L-19, 24, 25, 28

Tropical Products Institute

L19

The assessment of three timber species from Zambia for particle board manufacture

CFTRI LIBRARY MYSORE-24

LIBRARY AND DOCUMENTATION UNIT
Acc. No
Call No
C.F.T.R.I. MYSORE

Tropical Products Institute Report

L19

The assessment of three timber species from Zambia for particle board manufacture

A. E. Chittenden / L. J. Flaws / A. J. Hawkes

une 1970

Tropical Products Institute 56/62 Gray's Inn Road London WC1

Ministry of Overseas Development

This report was produced by the Tropical Products Institute, a British Government organisation which helps developing countries to derive greater benefit from their renewable resources.

It specialises in post-harvest problems and will be pleased to answer requests for information and advice. Reports such as this one are often written as the result of an enquiry.

Reproduction of this report, in whole or in part, is gladly permitted provided that full acknowledgement is given to the Tropical Products Institute, Ministry of Overseas Development and to the author or authors, where named.

Requests for further information should be addressed to:

The Director,
Tropical Products Institute,
56/62 Gray's Inn Road,
London, W.C.1.

Introduction

During a visit to the Tropical Products Institute by the Chief Forest Products Officer for the Republic of Zambia, the possibility of using the main plantation species of timber for the manufacture of particle board was discussed. The species involved are: *Pinus kesiya, Eucalyptus resinifera,* and *Eucalyptus grandis,* and it was agreed that samples of these trees should be dispatched to the Tropical Products Institute to enable particle board to be made in the laboratory, tested according to British Standard 1811: 1961, and the results compared with the British Standard Specification for Resin-Bonded Chipboard, 2604: 1963. It must be noted here that both these publications are based on Imperial Units and were used at the time this investigation was carried out. BS 1811: Part II: 1969, the metric version of the British Standard Methods of Test, has since been issued but was not used for these tests. The metric version of BS 2604 has not yet been issued, and the results quoted in this report are simple metric conversions of the test figures obtained in Imperial Units.

Description and preparation of samples

The samples each weighed about 350 kg. and consisted of a number of debarked logs, 750 mm. in length and from 100 to 180 mm. in diameter. They were prepared for board making separately, being cut into 250 mm. lengths, and then submerged in water for seven days, to ensure the minimum production of fines during flaking. At the end of this time they were removed from the tank and flaked on a machine with radial knives and scorers housed in a rotating disc. These were arranged to produce flakes 30 mm. long and 0·6 mm. thick. The flakes were dried from a moisture content of 40 per cent to about six per cent and were then passed through a hammermill fitted with a 13 mm. screen to produce particles 30 mm. long, 0·6 mm. thick and 1·5 to 3·0 mm. wide. These particles contained about 10·0 per cent of fines (i.e. material which would pass a 22 British Standard sieve) and at this stage were in a suitable condition for making into particle boards.

Board-making

A weighed quantity of particles was sprayed in a rotary mixer with commercial grade urea formaldehyde resin, containing 68 per cent of solids, using a modified paint spraygun. The weight of resin solids applied to the particles in this way is given in the extreme left-hand column of each of the Tables, and ranged from 8·0 per cent to 1·0 per cent of the dried (6·0 per cent moisture) weight of the particles. The sprayed particles were placed in a rectangular mould to form a loose mat which, after cold prepressing, was sufficiently compacted to be transferred to a heated hydraulic press, where it was subjected to a pressure of 14 kg/cm^2, and a temperature of 140°C for 15 minutes. This procedure produced finished particle boards measuring 370 mm. × 370 mm. × 19 mm. with a density of 640 kg/m^3 $\pm$ 30 kg/m^3.

During the course of this, and other similar investigations we were asked by Mobil (Europe) Inc., to try their proprietary wax emulsion Mobilcer 67, to see how it affected the water repellant properties of the boards. Duplicate boards were

therefore made under the same conditions both with and without 1·0 per cent of this wax emulsion for comparative purposes. This quantity of a proprietary wax emulsion, of which many types are available, is generally added during the commercial manufacture of particle board. There is no implication in this report that this particular product is better than or preferable to any other of the same type.

In addition, one set of boards was made by thoroughly mixing together equal weights of particles from each species using 3·0 per cent of resin and 1·0 per cent of 'Mobilcer 67'. The results of all these tests are given in Tables 1, 2, 3, and 4.

Discussion of results

It will be seen from **Table 1** that, when the resin content exceeds 5·0 per cent, the strength of the boards made from *Pinus kesiya* (as indicated by the modulus of rupture, the tensile stress perpendicular to the plane of board, and screw holding ability) remains substantially unchanged at a level considerably in excess of the minimum British Standard requirement. The resistance to the penetration of water at the same range of resin additions (as shown by the water absorption and thickness swelling) is generally poor unless 1·0 per cent of wax emulsion is used. With resin contents less than 5·0 per cent, the strength characteristics in general, gradually decrease, until, when only 2·0 per cent of resin is used, they approach the minimum value quoted in the British Standards Specification.

It will be noticed that none of the boards made from this species, satisfied the British Standards Specification on thickness swelling without the addition of wax emulsion, irrespective of the amount of resin used. Further, the water absorption figures were, without wax emulsion, not far below the permitted maximum figure.

E. resinifera and *E. grandis* **(Tables 2 and 3)** yielded, in general, weaker boards than *P. kesiya.* As with *P. kesiya,* the addition of wax emulsions at all resin contents makes a great improvement in the water-repellant properties of the boards from these two species; in the case of thickness swelling, its presence would appear to be essential to achieve the British Standards Specification maximum requirement irrespective of resin content. With both these species, the strength characteristics (as indicated by the modulus of rupture and tensile strength figures) were closely approaching (or below) the minimum British Standards Specification requirements at three per cent resin content. The previous tests on *P. kesiya* showed quite clearly that, without wax, the water absorption and thickness swelling figures were far above the required standard, and since the same trend was evident with these two Eucalypt species, it was decided to make and test boards at a resin content below 6·0 per cent.

Table 4 shows the test results from boards made by mixing equal weights of particles from each of the three samples of timber, together with 3·0 per cent of resin, and 1·0 per cent of wax emulsion. With the exception of thickness swelling which is just outside the limit, the test results are within the limits set by the British Standard. It must be noted that the tensile strength perpendicular to the plane is only just within the specification and the water-repellant characteristics are, even with wax emulsion, worse than any of the individual species at any resin content.

Conclusions

1. It is probably appropriate here, to give a brief explanation of the economic roles played by the normal synthetic binder (Urea formaldehyde resin) used in commercial particle board manufacture. It has become (possibly as a result of the great influence of the European industry using temperate species) the practice to produce particle boards having a density of about 640 kg/m^3 (40 lb. per cubic foot) for marketing reasons. At this density level, and using a wide range of temperate timbers, it is possible to produce boards fulfilling, with an adequate margin, the requirements

of the British Standards Specification, using about eight per cent of resin binder. At current prices this represents about 25 per cent of the manufacturing costs of the board. This is high enough and it is obviously advantageous if this figure can be reduced, whilst still keeping board strength above the specification.

2. The remarkable feature of this report is the outstanding board-making qualities of the *P. kesiya* material tested. Boards of a strength well within the British Standards Specification can be produced from this material at three per cent resin content. This clearly calls for a further investigation which at the moment, is in hand and will form the subject of a further report. At this stage however, it must be emphasized that these results only apply to this particular sample of *P. kesiya* examined. At present there is no evidence at all that other ages or provenances of this timber will behave similarly.

3. The two species of *Eucalyptus* timber are also excellent board-making materials and here again, the ability to produce boards of adequate strength from these species at lower resin contents is to be noted. It is not so pronounced as that of *P. kesiya* but is nevertheless also considered to be worthy of further investigation.

4. The results of this investigation clearly show the great advantages (and in some cases the necessity) of adding a wax emulsion to the boards.

5. There was one general abnormality noticed with all three species during these board-making trials. Although the moisture content of the sprayed mat was always at the same level (about 12 per cent), great difficulty was experienced in obtaining a sufficiently compressed and stable mat after the normal cold pre-pressing procedure. The practical result of this is that there is likely to be some difficulty in commercial practice in transporting the pre-pressed mat to the hot press without losing material from the edges. Possibly high cold pressing pressures would solve this problem, and this is also being investigated further.

Table 1
Pinus kesiya

Resin content per cent	'Mobilcer 67' content per cent	Density		Modulus of rupture		Tensile strength perpendicular to plane		Screw holding		Water absorption per cent	Thickness swelling per cent
		lbs/ft^3	Kg/m^3	lbs/in^2	Kg/cm^2	lbs/in^2	Kg/cm^2	lbs.	Kgs.		
8·0	Nil	41·2	660	3585	252	146	10·2	235	107	63·0	17·1
	1·0	41·2	660	3579	251	208	14·6	232	105	4·9	8·7
7·0	Nil	41·1	658	3773	265	177	12·4	243	110	51·5	17·9
	1·0	39·5	632	3231	227	173	12·1	219	100	4·2	10·1
6·0	Nil	40·5	648	3291	231	149	10·4	209	95	64·1	23·1
	1·0	39·8	637	3193	224	170	11·9	207	94	4·4	10·7
5·0	Nil	40·6	650	3587	252	139	9·7	196	89	70·0	20·4
	1·0	40·5	649	3375	237	163	11·4	199	90	5·3	3·2
4·0	Nil	40·7	651	2923	205	134	9·4	184	84	74·0	25·0
	1·0	40·1	642	2413	169	125	8·8	172	78	5·7	4·0
3·0	Nil	40·8	652	2793	196	106	7·4	163	74	84·0	28·9
	1·0	39·9	638	2637	185	105	7·4	163	74	5·0	3·5
2·0	—	—	—	—	—	—	—	—	—	—	—
	1·0	41·0	657	2380	167	53	3·7	111	50	6·5	5·7
1·0	—	—	—	—	—	—	—	—	—	—	—
	1·0	40·7	651	1466	103	22	1·5	46	21	8·6	9·8
BS 2604:1963				2000	140	50	3·5	80	36	75 (max)	12 (max)

Table 2
Eucalyptus resinifera

Resin content per cent	'Mobilcer 67' content per cent	Density		Modulus of rupture		Tensile strength perpendicular to plane		Screw holding		Water absorption per cent	Thickness swelling per cent
		lbs/ft^3	Kg/m^3	lbs/in^2	Kg/cm^2	lbs/in^2	Kg/cm^2	lbs.	Kgs		
8·0	Nil	41·4	663	3229	227	135	9·5	214	97	44·0	23·0
	1·0	41·3	662	3285	231	120	8·4	228	104	9·1	4·9
7·0	Nil	40·4	647	3218	226	153	10·7	247	112	39·0	16·6
	1·0	40·6	650	3355	236	129	9·1	217	99	9·2	5·4
6·0	Nil	40·2	644	3182	224	99	6·9	205	93	62·0	21·7
	1·0	40·9	655	3030	213	110	7·7	182	83	11·7	10·7
3·0	—	—	—	—	—	—	—	—	—	—	—
	1·0	40·9	655	2382	167	50	3·5	120	54	8·5	9·1
BS 2604:1963				2000	140	50	3·5	80	36	75 (max)	12 (max)

Table 3
Eucalyptus grandis

Resin content per cent	'Mobilcer 67' content per cent	Density		Modulus of rupture		Tensile strength perpendicular to plane		Screw holding		Water absorption per cent	Thickness swelling per cent
		lbs/ft³	Kg/m³	lbs/in²	Kg/cm²	lbs/in²	Kg/cm²	lbs.	Kgs.		
8·0	Nil	40·5	648	3197	225	157	11·0	227	103	48·0	24·1
	1·0	39·9	639	3587	252	145	10·2	194	88	5·7	3·0
7·0	Nil	40·1	642	3209	225	138	9·7	194	88	43·7	18·2
	1·0	40·8	654	3613	254	147	10·3	193	88	5·9	3·6
6·0	Nil	40·8	654	3505	246	138	9·7	196	89	40·0	19·9
	1·0	41·0	656	3738	262	113	7·9	162	74	6·5	4·3
3·0	—	—	—	—	—	—	—	—	—	—	—
	1·0	40·4	647	2686	189	48	3·4	113	51	8·3	6·2
BS 2604:1963				2000	140	50	3·5	80	36	75 (max)	12 (max)

MYSORE-2A
CFTRI LIBRARY

Table 4
Equal weight of *P. kesiya, E. resinifera* **and** *E. grandis*

Resin content per cent	'Mobilcer 67' content per cent	Density		Modulus of rupture		Tensile strength perpendicular to plane		Screw holding		Water absorption per cent	Thickness swelling per cent
		lbs/ft^3	Kg/m^3	lbs/in^2	Kg/cm^2	lbs/in^2	Kg/cm^2	lbs.	Kgs.		
3·0	1·0	40·6	650	2619	184	57	4·0	129	59	16·6	13·4

LIBRARY AND DOCUMENTATION UNIT
Acc. No
Call. No
C.F.T.R.I., MYSORE

Tropical Products Institute

L 24

The pulping characteristics of *Pinus caribaea* from Seaqaqa, Fiji

LIBRARY

Tropical Products Institute

L 24

The pulping characteristics of *Pinus caribaea* from Seaqaqa, Fiji

E. R. Palmer/J. A. Gibbs

April 1971

Tropical Products Institute
56/62 Gray's Inn Road
London WC1X 8LU

This report was produced by the Tropical Products Institute, a British Government organisation which helps developing countries to derive greater benefit from their renewable resources.

It specialises in post-harvest problems and will be pleased to answer requests for information and advice. Reports such as this one are often written as the result of an enquiry.

Reproduction of this report, in whole or in part, is gladly permitted provided that full acknowledgment is given to the Tropical Products Institute, and to the author or authors, where named.

Requests for further information should be addressed to:

The Director,
Tropical Products Institute,
56/62 Gray's Inn Road,
London WC1X 8LU.

D 659383 671

The pulping characteristics of *Pinus caribaea* from Seaqaqa, Fiji

SUMMARY

A sample of *Pinus caribaea,* approximately 10 years old, from Seaqaqa, Fiji, was pulped by the sulphate method.

The wood was pulped, without difficulty, by the sulphate process with chemical doses of 17·5 to 22·5% active alkali and yield 44 to 39% of screened pulp with Kappa numbers of 45 to 24.

These yields were a little lower than found in earlier examinations of *P. caribaea* at TPI.

The unbleached pulps had relatively high tearing strength and moderate tensile and bursting strengths. The pulps were similar to American Southern Pine pulps which are mainly used in integrated plants for the production of packaging grades of paper and newsprint.

The bleaching trials, which used a straightforward, three-stage technique, such as would be used commercially to produce a semi-bleached pulp, gave a brightness of 66%, but it is probable that with more sophisticated techniques fully bleached pulp could be produced. The fibres are rather coarse and for writing and printing papers the pulp should be mixed with hardwood pulps.

The results are compared also with the results from similar trials of temperate pulpwoods and from an earlier trial on three samples of *P. caribaea* from Fiji that were reported in TPI Report L14. Details are given of soil and climatic conditions, of the tending of the plantation and of the growth increment. The density of the wood was 0·46 g/cm.^{3} The bark content was rather high, averaging 34% by volume. The chemical composition and the fibre dimensions were similar to those found in earlier examinations of *P. caribaea.*

INTRODUCTION

Pinus caribaea, a tropical species native to the Caribbean area, was introduced to Fiji about 1955. The rate of growth on several sites was found to be good, and this led to a keen interest in the species as a potential source of pulpwood. Material from three sites, Drasa, Nadarivatu and Verata, was sent to the Tropical Products Institute for examination in 1966, when the best pulps were reported to be equivalent or slightly inferior to American Southern Pine pulps.[1] In this report the results of an examination of *Pinus caribaea* from another site, at Seaqaqa, are compared with those from the earlier examination. Full details of the growing conditions at Seaqaqa and of the history of the plantation are given in Appendix I.

Samples

The trees used in this investigation were planted in January/February 1960 and cut down in January 1970. A plot of 100 trees was marked within the plantation and five trees selected by random numbers. The length of the trunk of the tree to a diameter of 3 inches under bark was measured and 1-foot billets cut at 10, 30, 50, 70 and 90% of this height. Full details of the dimensions of trees and billets, as supplied by the Forest Department, are in Table 1.

Each billet was then split in half lengthways and one half sent to the Tropical Products Institute after treatment with insecticides and fungicides.

An equal number of ¾-inch slices was sawn from each billet and these were split into chips which were mixed and bulked. The aliquots taken for the trials should thereby have been representative of the plot.

Experimental Methods

In order to facilitate comparison with earlier results the methods used were, with one exception, those used in TPI Report L14. The exception was the measurement of brightness; we have replaced our EEL brightness meter with an Elrepho instrument. The significance is discussed in the appropriate part of the report.

Details of experimental techniques are given in Appendix II.

Apparent Density

The apparent density of each sample is given in Table 2. The variation within each tree was greater than the differences of the mean densities of the trees. The mean density for the site (0·46 g/cm^3, 28·7 lbs/ft^3) was similar to that for the Drasa and Verata sites (both 0·44 g/cm^3, 27·5 lbs/ft^3), but much greater than that for the Nadarivatu site (0·31 g/cm^3, 19·3 lbs/ft^3).[1]
The density of all the Fiji samples were within the range for the density of softwoods used in the pulp industry.

Bark/Wood Ratio

The amount of bark expressed as a percentage of the total volume of the log (ie wood plus bark) is also given in Table 2. For the billets, this figure covered a wide range, from 16 to 51% with an average of 34%; from tree to tree the range was 32 to 37%. This is much higher than that found in temperate pulpwoods, which is quoted as about 15%.[2]

Chemical Examination

The main chemical constituents, expressed on the oven dry (o.d.) wood were:

	Seaqaqa	Drasa[1]	Nadarivatu[1]	Verata[1]
Alcohol–Benzene solubility, %	2·4	2·7	2·8	2·1
Holocellulose, %	59·6	59·6	62·1	63·8
Alpha-cellulose, %	38·0	39·7	39·0	42·5
1% NaOH solubility, %	13·9	12·4	12·4	10·8
Lignin, %	29·9	–	–	–

The present sample had a slightly lower cellulose content than the earlier samples so that a slightly lower yield of pulp was anticipated, but no other pulping problems were foreseen from the analyses. Subsequent pulping trials confirmed this.

Fibre Dimensions

The following are the mathematical averages of measurements made on fibres in a suspension of a well-cooked unbeaten sulphate pulp.

	Seaqaqa	Drasa[1]	Nadarivatu[1]	Verata[1]
Length of all fibres, whole *and* broken, mm	2·2	2·2*	2·2*	2·3*
Length of *whole* fibres only, mm	3·1	2·6	2·9	2·9
Apparent fibre width, microns	54·3	54·8	61·6	53·2
Apparent fibre wall thickness, microns	5·5	5·2	4·6	5·7

*Subsequent measurements not quoted in L14

There was no very significant difference in the fibre dimensions of fibres in the four pulps, and all of the samples might be expected to yield similar pulps. This was found to be only very broadly the case.

The range of fibre lengths and widths is illustrated in the histogram. This shows that the range of lengths of whole unbroken fibres, as might be found in the tree, was wide—from very short to 7·5 mm—with no particularly predominant length group. During pulping, a large proportion of fibres have broken; as typically happens, and more than half of the number of fibres in the pulp were less than 2 mm long. The range of width was also large (from 10 to 100 microns) but half the fibres were in the range of 40 to 60 microns.

Pulping and Pulp Evaluation

No difficulty was experienced in pulping by the sulphate process. Details of pulping conditions and pulp yields are given in Table 3.

The samples from Seaqaqa needed digestion conditions similar to those used for samples from Nadarivatu and Verata, but less severe than for the sample from Drasa. The figures for per cent yield of unbleached pulp screened or unscreened, were 5 or 6 lower than for pulps of equivalent Kappa number in the earlier trial.

The results (given in full in Table 4 and interpolated at 500 and 300 CSf in Table 5) indicate that for pulps for the present samples with a Kappa number above 30, there was little difference in rate of beating, and in strength except for tear; the more severely cooked pulp responded more quickly to beating and was weaker.

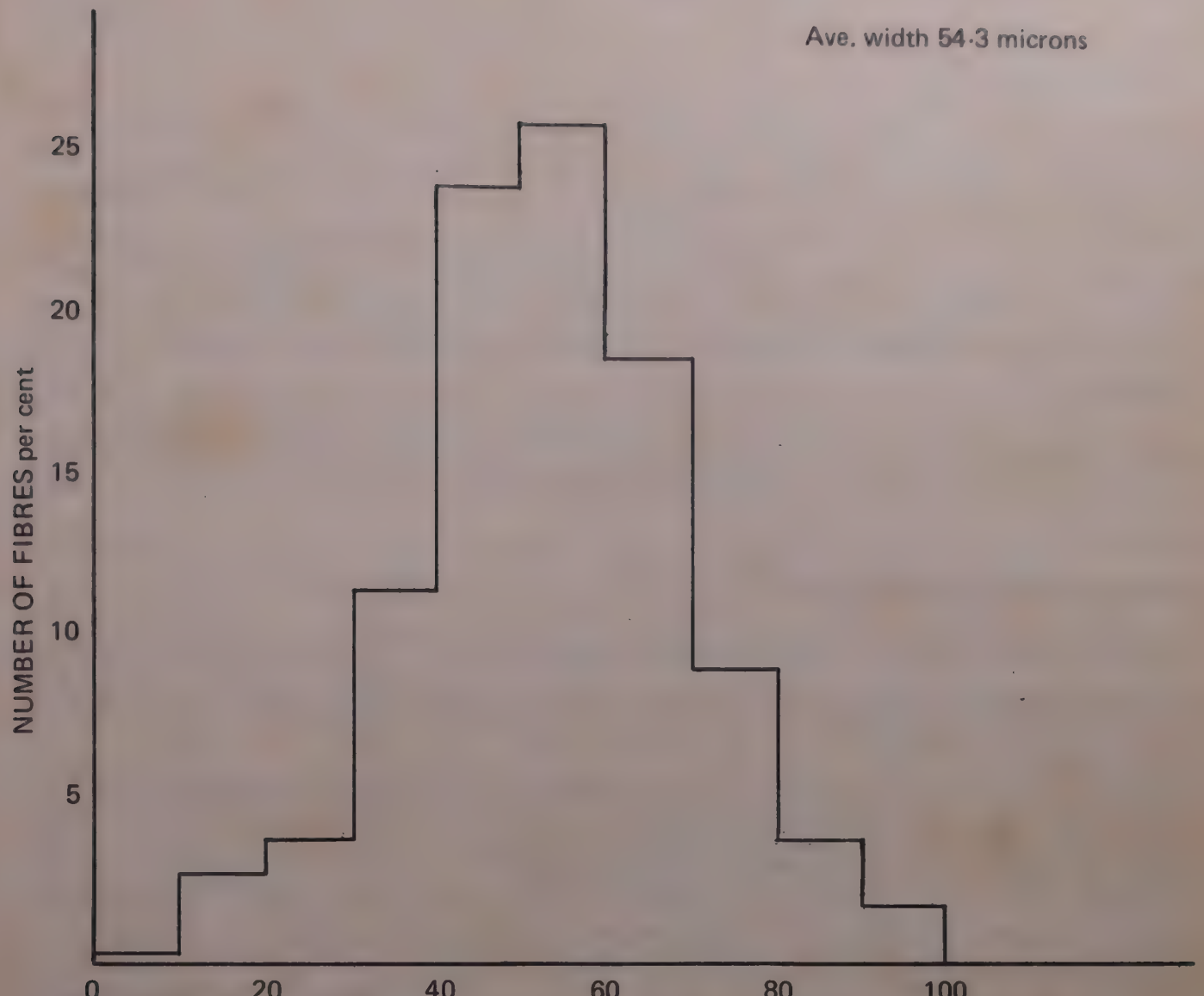
For comparison, evaluations of unbleached pulps at 500 and 300 CSf obtained in the earlier work from wood samples from Drasa, Nadarivatu and Verata are given in Table 6. The present sample from Seaqaqa was most like the earlier sample from Verata.

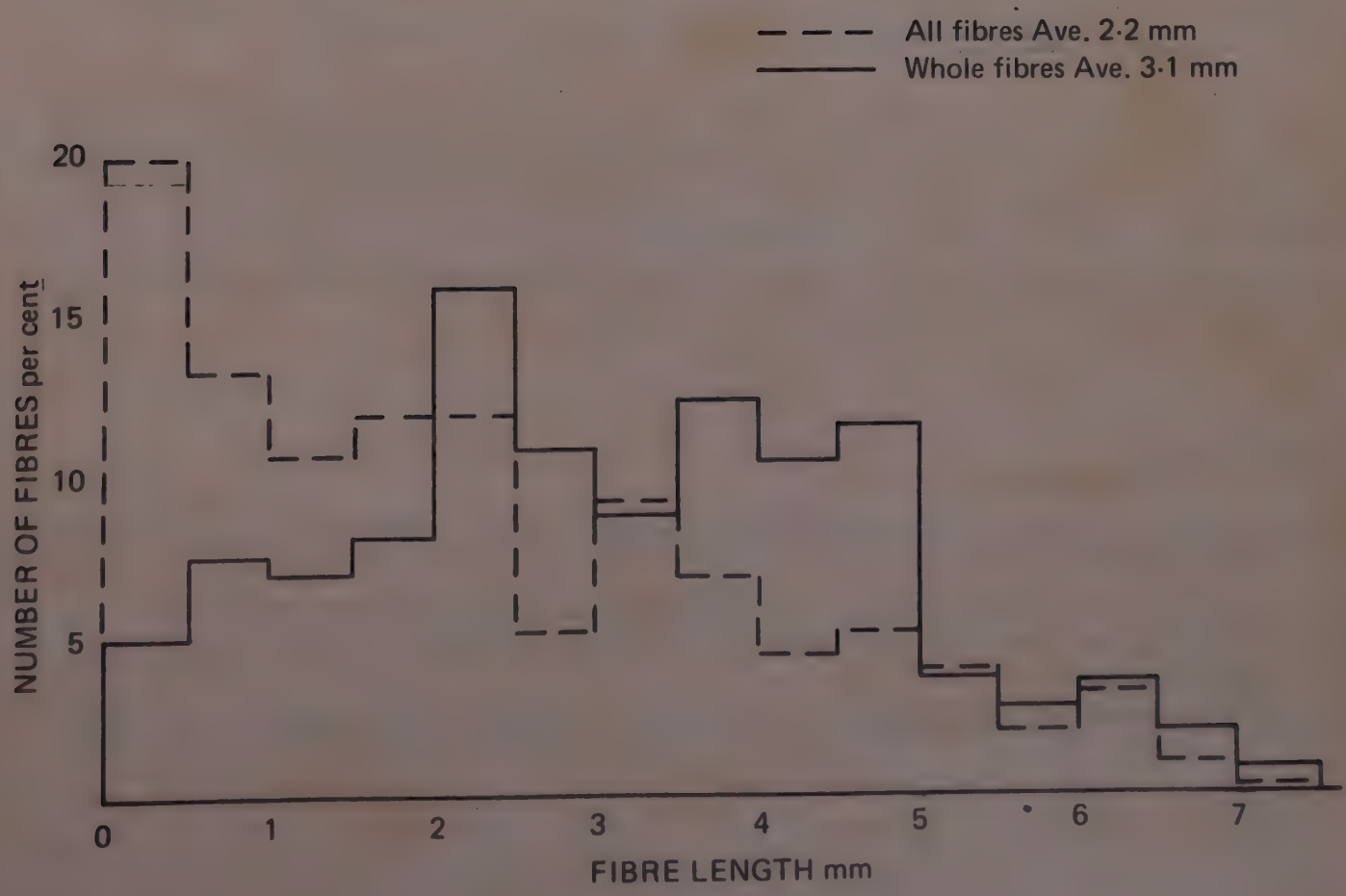
Bleaching and Bleached Pulp Evaluation

The unbleached pulp with the lowest residual lignin content (Cook K400) was bleached using the same three-stage sequence (chlorination, alkali extraction, hypochlorite) as was used in the earlier examination. This is a very simple sequence and would only be used commercially to produce a semi-bleached pulp; a more complex sequence, using more stages and possibly chlorine dioxide, would be used to produce a fully bleached pulp.

Details of the bleaching and bleached pulp evaluation are given in Table 7. The bleaching conditions were similar to those used in the earlier trial.

PINUS CARIBAEA SEAQAQA FIJI





In summary:

Total chlorine added on o.d. unbleached pulp	7%
Yield, o.d. bleached pulp on o.d. unbleached pulp	93%
Yield, o.d. bleached pulp on o.d. wood	36·4%
Brightness Elrepho 457 nm (MgO = 100)	66%

The brightness was apparently much lower than was obtained with the earlier samples, but this difference was mainly due to the use of a new instrument conforming to ISO recommendations. Had it been possible to measure brightness in exactly the same way as was used earlier, this sample would have had a similar result to the Verata sample. Scots pine bleached under similar conditions gives a similar brightness of about 66%. With more elaborate bleaching in commercial plants a high brightness can be obtained with Scots pine and this suggests that satisfactory brightness could be obtained with this *P. caribaea.* The lower yield of bleached pulp reflect the lower yield of unbleached pulp.

The bleached pulp had about the same breaking (tensile) and bursting strengths but a lower tearing strength than the unbleached pulp from which it was obtained.

Comparison with Commercial Pulps

The results of pulp evaluation of a pulp made in this laboratory from a temperate pine, *P. sylvestris,* and of two unbleached commercial kraft pulps, are given in Table 8. Both of the commercial pulps are of a sort more likely to be used in an integrated mill than to be sold as market pulps.

The pulp made from *P. caribaea* from Seaqaqa had better tearing strength but poorer bursting and breaking (tensile) strengths than the *P. sylvestris* pulp. Compared directly with the commercial pulps the strength figures for the *P. caribaea* pulps were equal or slightly better. However, allowance must be made for factors that might lead to any wood yielding a weaker pulp when pulped commercially than when pulped in the laboratory. The commercial pulps had been formed into dry pulp laps (8 to 10%) moisture and for pine pulps the loss in strength may be as much as 16% when sheeted on a feltless uptaking machine with dryer.[3] Further, the chips used in the laboratory had been split along the grain with a guillotine and it has been shown that pulps from chips prepared in this way are often stronger than pulps prepared from mill chips from the same wood. From published data this effect is much smaller than the effect of sheeting and drying,[4] but it would contribute to the lower strength of a commercial pulp.

Allowing for these factors the probability is that commercially made pulps from this sample of *P. caribaea* would be a little weaker than Southern Pine pulps, but could nevertheless be used in the same way for the production of packaging grades of paper in an integrated plant.

The bleaching trials on this sample were not sufficient to reach any firm conclusions about bleached pulp but the tentative conclusions are that a bleached pulp of adequate strength and brightness for writing and printing papers could be made if more stages of bleaching, including chlorine dioxide, for example, were used. The surface of the paper would be rather rough because of the coarseness of the fibres. It is likely that better writing and printing papers would be made if the *P. caribaea* pulp were mixed with a hardwood pulp than with the softwood alone.

REFERENCES

1. E. R. PALMER and J. A. GIBBS, Pulping characteristics of *Pinus caribaea* from Fiji, TPI Report L14, 1968.
2. J. P. CASEY, Pulp & Paper, Vol. 1, p. 75, Interscience Publishers Inc., New York 1960.
3. H. A. REID, Pine Pulp—Strength loss on lapping. Presented at the Appita Conference, Carbena, March 1966.
4. L. E. LARSEN, Current Work on the New Soderham Chippers, *TAPPI,* 1967, **50**, No. 2, 61A.

Tables

Table 1

***Pinus caribaea* from Fiji**

Location: Seaqaqa, Vanua Levu, p. 60 *P. caribaea* (plot permanently demarcated).

Material: 5 half billets, from each of 5 trees selected at random from a plot of 100. Samples taken at 10, 30, 50, 70 and 90% of length, length being measured to 3 inches u.b. diameter (ø).

Date: Samples collected 6.1.70, consigned 8.1.70.

Tree Number	Height, feet and inches		Billet girth in inches (to nearest ¼ inch)									
	Total height	Ht. to 3 inches ø u.b.	10%		30%		50%		70%		90%	
			o.b.	u.b.	o.b.	u.b.	o.b.	u.b.	o.b.	u.b.	o.b.	u.b.
77	47 8	29 3	28½	22¼	25¼	21	23	18¾	19½	16½	16½	14
70	53 10	34 6	26	18½	21	17	18½	15	16½	14	14	11½
55	45 2	30 0	24½	19¼	22½	17½	20¼	16¾	20¼	16	15	12
45	56 6	39 1	32	24¼	27½	23	23½	20	20¼	17½	15	13
34	55 6	38 3	27¼	21½	24	19¼	19½	17	17	15	12¼	11¼

u.b. under bark
o.b. over bark

Table 2

Pinus caribaea from Fiji

Apparent density and percentage bark

Disc Number	Apparent Density g/cm^3	Apparent Density lbs/ft^3	Bark, % by volume
F 34/1	0·51		51
F 34/3	0·48		36
F 34/5	0·46		24
F 34/7	0·49		22
F 34/9	0·47		16
Mean for Tree F34	0·49	30·3	34
F 45/1	0·48		43
F 45/3	0·45		30
F 45/5	0·47		28
F 45/7	0·45		25
F 45/9	0·55	Disc included a large knot	25
Mean for Tree F45	0·47	29·5	32
F 55/1	0·50		38
F 55/3	0·43		40
F 55/5	0·41		33
F 55/7	0·39		38
F 55/9	0·41		36
Mean for Tree F55	0·43	27·0	37
F 70/1	0·52		49
F 70/3	0·53		35
F 70/5	0·42		34
F 70/7	0·47		28
F 70/9	0·40		33
Mean for Tree F70	0·48	30·1	37
F 77/1	0·45		39
F 77/3	0·46		31
F 77/5	0·42		34
F 77/7	0·41		28
F 77/9	0·42		28
Mean for Tree F77	0·44	27·3	33
Mean for five trees on site	0·46	28·7	34

$$\text{Apparent Density} = \frac{\text{Green (soaked) volume}}{\text{Oven dry weight}}$$

$$\text{Bark Ratio} = \frac{\text{Volume of bark} \times 100}{\text{Volume of wood and bark}}$$

Table 3

Pinus caribaea **from Fiji**

Sulphate digestion conditions

Conditions Common to all Cooks

Sulphidity, %	25
Liquor to oven dry wood ratio, l/kg	6:1
Time to reach maximum temperature, hour	1
Time at maximum temperature, hours	4

Cook number	K403	K398	K397	K400
Digestion Conditions				
Active Alkali as Na_2O, % oven dry wood	22·5	17·5	20	22·5
Maximum Temperature, °C	160	170	170	170
Active Alkali consumed as Na_2O, % oven dry wood	12·6	12·9	13·5	13·4
Yield				
Oven dry unbleached pulp on oven dry wood, %	44·4	42·5	39·7	39·2
Oven dry screened unbleached pulp on oven dry wood, %	44·3	42·4	39·6	39·1
Screenings (using 0·15 mm slits) on screened pulp, %	0·2	0·2	0·1	0·1
Kappa number	44·5	42·8	31·4	24·5

Note: Definitions of terms and details of procedure will be found in the appendix.

Table 4

Pinus caribaea **from Fiji**

Unbleached sulphate–pulp evaluation

Valley beater

Cook Number	Kappa Number	Beating Time, minutes	Basis Weight g/m²	Thickness microns	Bulk ml/g	Burst Factor	Breaking Length, metres	Stretch, %	Tear Factor	Double Folds Kohler-Molin 600 g	Drainage Time, seconds	Canadian Standard freeness	Air porosity, sec/100 ml/in²
K403	44·5	0	60·6	125	2·069	32·7	5367	4·3	183	5404	4·4	735	0·5
AA 22·5		15	59·8	104	1·744	47·7	6895	4·9	200	9958	4·5	695	2·4
Temp 160°C		30	60·7	100	1·642	53·8	7689	5·1	196	7256	4·6	635	6·7
Time 1 + 4 hrs		45	59·4	96	1·611	58·2	8344	5·2	198	7360	4·8	545	20·8
Yield 44·3		60	60·4	90	1·488	64·4	9341	5·1	184	10572	5·2	440	125·0
		75	59·8	92	1·530	67·6	9348	4·8	206	8609	6·1	335	542·7
		90	59·6	87	1·458	70·0	9620	5·0	185	10312	9·0	210	over 1000
K398	42·8	0	61·0	127	2·077	31·0	4879	4·1	187	5524	4·4	720	0·5
AA 17·5		15	61·2	102	1·657	46·7	7173	4·8	183	6296	4·5	690	2·8
Temp 170°C		30	59·0	96	1·627	52·9	8071	4·5	184	7019	4·6	625	8·6
Time 1 + 4 hrs		45	59·8	94	1·571	59·1	8620	5·0	191	6573	5·0	525	40·3
Yield 42·4		60	62·1	95	1·523	65·0	9166	5·0	182	7581	5·2	405	188·4
		75	60·2	88	1·463	65·6	9323	4·8	179	7120	6·3	300	over 1000
		90	56·9	82	1·448	67·8	10202	4·6	182	8269	10·2	200	over 1000
K397	31·4	0	58·2	116	1·988	31·6	5270	3·9	178	3489	4·4	720	0·6
AA 20		15	59·7	100	1·673	47·1	6927	4·5	178	5685	4·5	695	2·8
Temp 170°C		30	59·6	93	1·556	51·2	7886	4·2	171	6339	4·6	625	7·8
Time 1 + 4 hrs		45	61·1	91	1·495	59·4	8803	4·5	169	5946	4·8	535	29·3
Yield 39·6		60	58·9	88	1·501	62·3	9118	4·3	166	6695	5·1	460	119·7
		75	60·5	88	1·447	63·9	9536	4·5	161	5950	6·4	310	751·4
		90	60·3	84	1·387	65·2	9850	4·3	152	8230	10·4	210	over 1000
K400	24·5	0	60·1	110	1·824	33·4	5539	4·2	163	4760	4·4	720	1·0
AA 22·5		15	56·5	90	1·598	42·8	6824	5·1	171	5336	4·6	710	1·7
Temp 170°C		30	58·7	91	1·546	50·9	7475	4·3	158	5455	4·7	610	10·0
Time 1 + 4 hrs		45	58·1	89	1·526	55·4	8307	4·0	157	6389	4·9	500	35·0
Yield 39·1		60	61·4	87	1·422	59·1	8616	4·5	162	6108	5·9	330	269·0
		75	59·7	86	1·432	63·6	9421	4·1	153	7384	8·5	230	over 1000

Table 5

Pinus caribaea, **Seaqaqa**

Unbleached sulphate pulp evaluation

Interpolation at 500 and 300 Canadian Standard freeness

Cook Number	Kappa Number	Yield of screened unbleached pulp, %	CSf	Beating Time, Valley Beater, minutes	Bulk ml/g	Burst Factor	Breaking Length, metres	Tear Factor
K403	44·5	44·3	500	51	1·59	62	8800	196
			300	78	1·49	68	9500	190
K398	42·4	42·4	500	48	1·56	62	8900	181
			300	75	1·48	67	9500	180
K397	31·4	39·6	500	50	1·50	61	9000	168
			300	77	1·43	65	9600	160
K400	24·5	39·1	500	44	1·50	55	8100	160
			300	66	1·45	60	9000	155

LIBRARY AND DOCUMENTATION UNIT
Acc. No
Call. No
C.F.T.R.I., MYSORE

Table 6

Pinus caribaea **from Fiji (earlier samples)**

Unbleached sulphate pulp evaluation

Interpolated at 500 and 300 Canadian Standard freeness

(Results originally reported in TPI Report L14)

Site	Cook Number	Kappa Number	Yield of screened unbleached pulpwood, %	CSf	Beating Time, Valley Beater, minutes	Bulk ml/g	Burst Factor	Breaking Length, metres,	Tear Factor
Drasa	K216	43	50·7	500	51	1·50	72	9700	205
				300	70	1·46	75	10300	200
	K215	28	45·0	500	48	1·50	68	9000	230
				300	68	1·45	72	9700	225
	K291	22·5	43·9	500	56	1·49	42	6400	85
				300	78	1·44	44	7000	80
Nararivatu	K237	34	46·7	500	71	1·42	74	9400	125
				300*					
	K217	24	46·9	500	65	1·41	60	8500	115
				300*					
Verata	K236	32	49·1	500	52	1·56	62	7700	200
				300	76	1·48	66	8600	185
	K218	23	45·6	500	45	1·54	60	8100	180
				300	64	1·49	66	9000	175

* Values at 300 CSf were not determined as after 90 minutes beatings the CSf was greatly in excess of this value.

Table 7

***Pinus caribaea* from Fiji**

Bleached sulphate pulp evaluation

Valley beater

Cook Number	Kappa Number	Chlorination	Alkaline Extraction	Hypochlorite	Beating Time, minutes	Basis Weight, g/m^2	Thick-ness, microns	Bulk ml/g	Burst Factor	Break-ing Length, metres	Stretch %	Tear Factor	Double Folds, Kohler-Molin 600g	Drain-age Time, seconds	Canadian Standard freeness	Air porosity, sec/ 100 ml/ in^2	Bright-ness, Elrepho 457 nm MgO=100	Printing Opacity, %
K400	24·5	Chlorine, added 4·5%	NaOH, added 3%	Available Cl_2, added 2·5%	0	60·9	104	1·707	29·6	5008	4·6	148	4311	4·5	755	1·0	66	73
		Consistency, 3%	Consistency, 6%	Consistency, 6%	15	58·7	90	1·535	47·0	7268	4·3	143	5944	4·5	680	5·8		65
		Temperature, 20°C	Temperature, 60°C	Temperature, 35°C	30	61·9	89	1·442	53·5	7686	4·1	131	6091	4·8	570	38·4		63
		Time, 1 hr	Time, 1 hr	Time, 2 hrs	45	60·0	84	1·398	57·0	9052	3·9	135	5399	5·8	385	316·5		61
					60	59·6	81	1·363	60·6	9428	3·9	126	6793	10·2	230	over 1000		57
					75	58·3	76	1·308	61·9	9920	4·0	116	8974	28·2	125	over 1000		55
					90	59·9	75	1·256	61·0	9816	4·2	108	11527	99·0	60	over 1000		51

Table 8

Unbleached sulphate pulp evaluation

Valley beater

Interpolations at 500 and 300 Canadian Standard freeness

Pulp	Kappa Number	CSf	Bulk ml/g	Burst Factor	Breaking Length, metres	Tear Factor
Scots Pine, U.K., laboratory-made pulp	34	500	1·47	90	11800	140
		300	1·43	95	12000	135
Southern Pine, U.S.A., commercial pulp	35	500	1·57	56	7600	185
		300	1·54	63	8700	185
North American commercial kraft pulp	32	500	1·60	62	8400	165
		300	1·50	68	9400	155

Appendices

APPENDIX I

Growing conditions at Seaqaqa and history of plantation

The following information about the growing conditions and growth rate was provided by the Forest Department in Fiji.

Climate

The rainfall and climatic environment corresponds to Classification I of Twyford and Wright ('The Soil Resources of the Fiji Islands'), that is

Lowland climate with strong dry season	
Mean annual temperature	78°F
Mean annual rainfall range	55 to 100 inches
Average number of months with less than 4 inches rainfall	5½
Average number of months with less than 2·36 inches rainfall	3
Average soil moisture deficit during any part of year	3 inches (Aug.-Nov.)
Average surplus moisture for leaching during any part of year	12 inches (Jan.-April)
Thornthwaite rational classification	$C_2A^1\ a^1r$

Soil Condition

The soil is classified as 'ferruginous latosol' ('Talasiga').

The soil from a site immediately adjacent to that from which samples were taken was analysed by the Fiji Department of Agriculture in 1966 with the following result.

	Top Soil	Sub Soil
pH H_2O	4·70	4·65
pH $CaCl_2$	4·05	4·00
Total N %	0·14	0·09
Organic C %	2·43	1·04
C : N ratio	17	12
Total P_2O_5 ppm	1263	1632
Available P_2O_5 ppm	9	9
Available CuO ppm	633	463
Available MgO ppm	723	755
Available K_2O ppm	28	21
Available Na_2O ppm	88	86
Colour	Dark reddish brown	Red
Colour number	2·5YR3/4	2·5YR4/6
Texture	Sandy loam	Sandy loam
Clay, %	16	18
Silt, %	10	12
Sand, %	74	70

Height above sea-level: 300 feet

Natural Vegetation: Fern, reed, mile-a-minute, casuarina, wire grass.

Species

Pinus caribaea var *hondurensis* planted 1960. The seed source was British Honduras, but the records do not indicate the exact source. However, from the collections made in British Honduras at that time, it was safe to assume it was Mountain Pine Ridge.

Growth Data

The plantation was planted in January-February 1960, with an original spacing of 9 feet by 9 feet (540 trees/acre).

Pruning and thinning was carried out as follows:

(1) First pruning to ⅓ overall height in 1964.
(2) Second pruning to 22 feet in October 1968.
(3) 1967 plantation thinned down to 380 stems/acre.
(4) 1969 plantation thinned down to 250 stems/acre.
(5) A light thinning was carried out in 1965 following the December 1964 hurricane.

Measurements were made on a 0·2 acre sample plot in September 1967 as follows:

Trees/plot 76	(Trees/acre 380)
Basal area/plot 22·7 ft^2	(BA/acre 113·5 ft^2)
Diameter range	4·1 inches to 11·0 inches
Plot mean height	48 ft

Total stem volume (under bark):

Diameter class	No of trees	Glass Vol (ft^3)
4	7	13·51
5	11	31·46
6	14	55·72
7	21	111·09
8	9	61·11
9	10	84·80
10	3	31·05
11	1	12·41

Total stem volume/plot 401·15 ft^3 (Total stem volume/acre 2005 ft^3)

(Note: Mean annual increment shortly after the first thinning at seven years was 287 ft^3/acre on this plot)*

Further measurements on three 0·1 acre plots in January 1970 yielded the following:

Plot number	1	2	3
Times pruned	2	2	2
Average height of pruning, feet	28	28	28
Times thinned	2	2	2
Number of trees in plot	24	24	24
Dominant mean height, feet	63·9	55·2	56·8
Dominant mean diameter, inches	9·65	10·15	9·65
Plot mean height, feet	61·0	48·6	50·9
Basal area, $feet^2$	9·24	7·12	8·04
Total plot volume, $feet^3$ under bark	202·4	124·2	147·3

*(Note: The M.A.I. at 10 years, a few months after the second thinning from 380 to 250 trees per acre, appears to average 158 ft^3/acre for these three plots. Supposing the time interval between thinning and measurement was short, the M.A.I. of pulpwood at 10 years would have been less than 158 x 380/250 = 240 ft^3/acre assuming the thinned trees were the weaker).

APPENDIX II

Details of experimental methods

Bark/Wood Ratio

The proportion of bark to wood on a volumetric basis was calculated from the dimensions given by the Forest Department using the following formula:

$$\text{Bark \%} = \frac{(d_a^2 - d_b^2)}{d_a^2} 100$$

Where d_a = diameter overbark

Where d_b = diameter underbark

Physical Examination

One complete disc approximately 1 inch thick was cut from near each end of each leg. The Apparent density was determined by the water displacement method TAPPI Standard Method T18.[1]
The result for each log represents the average of the two determinations.

Chemical Examination

One disc from each log was ground in a knife mill and the fraction of the groundwood which passed a BS40 mesh sieve (420 microns) and which was retained on a BS60 mesh sieve (250 microns) was used for analysis. The methods used were:

Alcohol–Benzene solubility	TAPPI T6m[1]
Holocellulose	Wise, Murphy and D'Addieco[2]
Alpha-cellulose	TAPPI T203 os[1]
1% caustic solubility	TAPPI T4m[1]
Lignin	TAPPI T13m[1]

Microscopic Examination

The fibre dimensions were determined using the dispersed fibres from an air-dried standard sheet from a well-cooked sulphate pulp. The fibres were mounted in an aqueous medium and the length, width of the partially collapsed fibre and the fibre wall thickness of at least 400 fibres measured. The length of the fibre was measured twice: first including all fibrous elements, whole and broken; second including only fibres which appeared intact, in that their ends appeared to terminate naturally and not as a result of fracture.

Pulping Trials

Pulping trials were carried out on a composite sample from each site. All of the logs were cut into discs approximately ¾ inch thick and the discs were split along the grain into chips about ¼ inch thick by ¾ inch wide with a small powered guillotine. All of the chips from one site were mixed thoroughly to obtain the sample for pulping.

Digestions, using the sulphate (kraft) process, were carried out in a 15-litre, stainless-steel, electrically heated, rotating digester. The active chemicals in the sulphate process are sodium hydroxide and sodium sulphide. The terms 'Active Alkali' and 'Sulphidity' are defined as:

Active Alkali = $NaOH + Na_2S$, expressed as Na_20 equivalent, per cent on oven-dry wood.

$$\text{Sulphidity} = \frac{Na_2S \times 100}{NaOH + Na_2S}$$ in which all the Na compounds are expressed as Na_20.

The cooked chips were dumped from the digester, disintegrated to simulate the effect of blowing and were fine screened with 0·15 mm slots; 80 mesh/inch sieves were used for washing and collecting the pulp after screening. Yield was determined after screening and the yield of digested pulp calculated.

The excess alkali was estimated by titration to pH 8·3 after the addition of barium chloride.

The Kappa number (which is proportional to the lignin content of the pulp) was determined by TAPPI Standard Method T236[1] using screened pulp.

Bleaching Trials

Bleaching trials were carried out by a simple three-stage method using chlorination with chlorine water, alkali extraction and hypochlorite bleach. The conditions for chlorination were determined using the orienting trials described in 'Raw Materials for More Paper'.[4]

Pulp Evaluation

Both unbleached and bleached pulps were evaluated. The pulps were beaten in a Valley Niagara Beater with a 5·5-kg load on the bed plate. Standard sheets from unbeaten and beaten pulps were made according to British Standard Methods[5] and tested after conditioning at 68° ± 3°F and 65 ± 2% relative humidity.

REFERENCES

1. TAPPI Standard and Suggested Methods, Published by the Technical Association of the Pulp and Paper Industry, New York.
2. L. E. WISE, M. MURPHY and A. A. D'ADDIECO, *Paper Trade J.* 1946, **122**, No. 2, 35.
3. W. E. SPEARIN and J. H. ISENBERG, *Science*, 1947, **105**, No. 2721.
4. Raw Materials for More Paper, FAO Forestry and Forest Products Study No. 6, Rome, 1953.
5. Second Report of the Pulp Evaluation Committee to the (British) Paper Makers' Association, London, 1936.

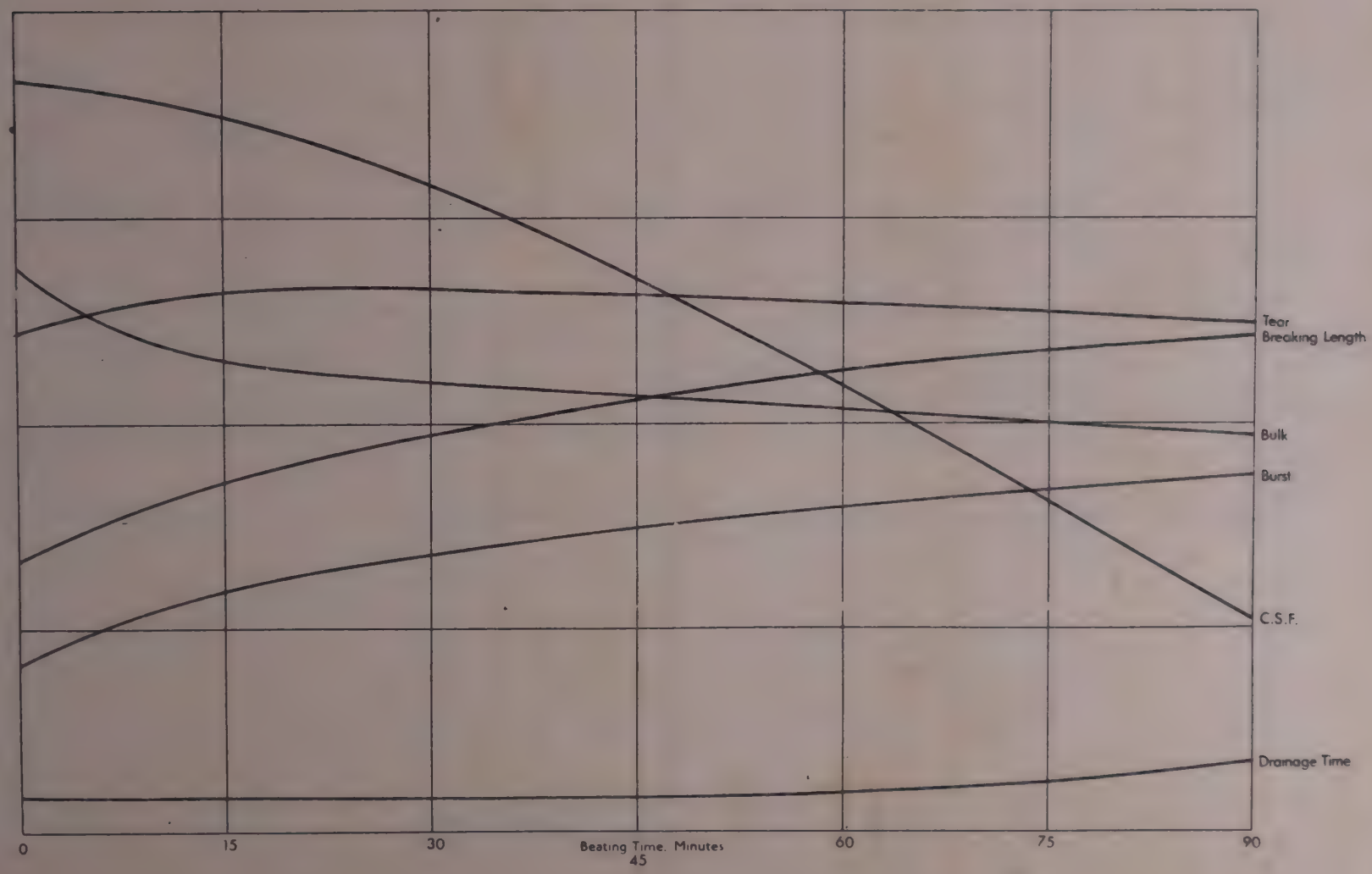
TROPICAL PRODUCTS INSTITUTE LONDON PULP & PAPER SECTION

PULP EVALUATION : BEATING CURVES

Raw Material Pinus caribaea Seaqaqa Fiji
Type of Pulp Unbleached Sulphate
Type of Beater Valley

File No
Cook No K 403

C.S.f. ml	Drainage Time sec	Bulk ml/g	Burst Factor	Breaking Length metres	Tear Factor
800	100	3.00	160	16000	300
600	75	2.25	120	12000	225
400	50	1.50	80	8000	150
200	25	0.75	40	4000	75
0	0	0	0	0	0

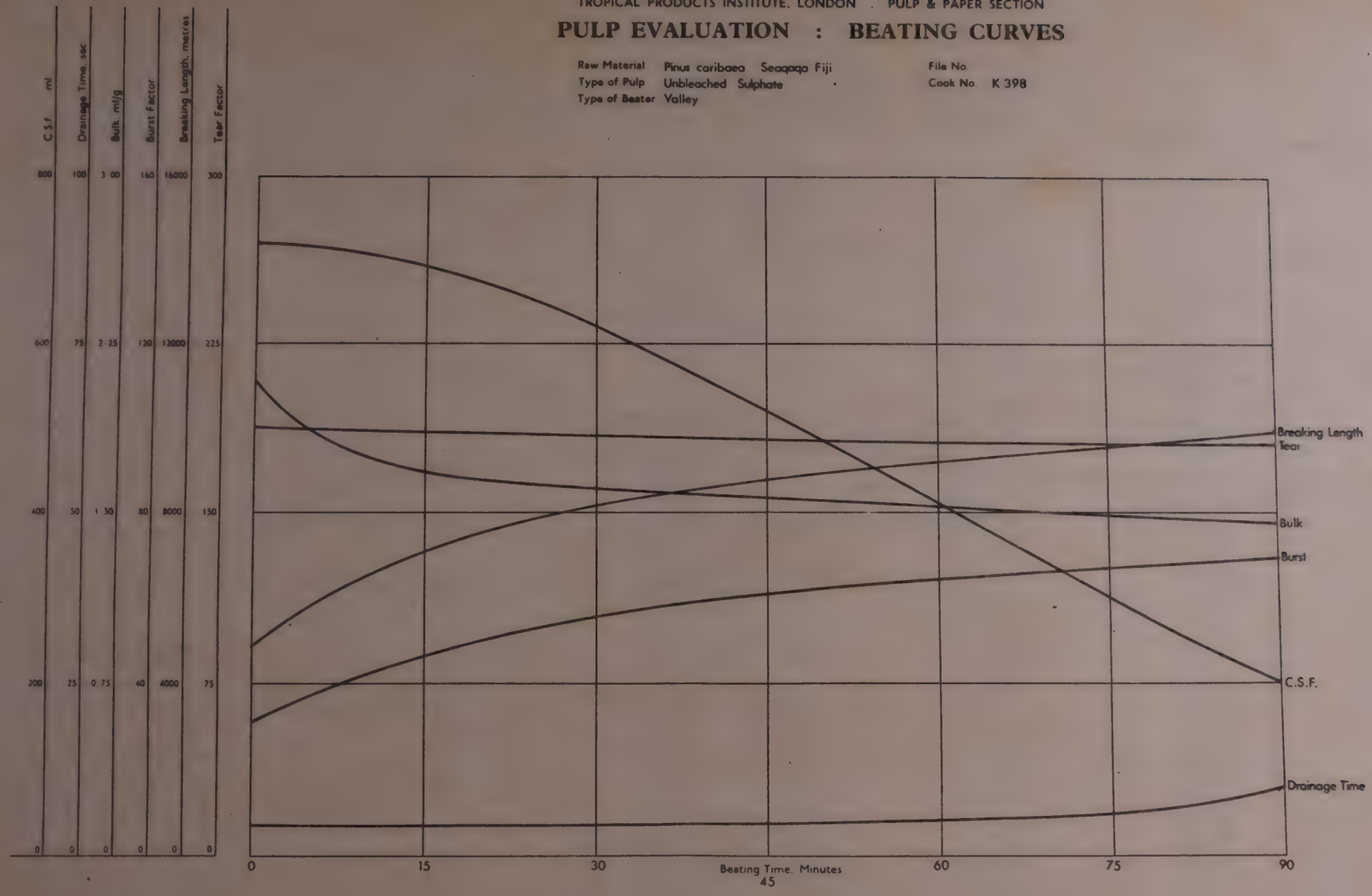


TROPICAL PRODUCTS INSTITUTE, LONDON . PULP & PAPER SECTION

PULP EVALUATION : BEATING CURVES

Raw Material Pinus caribaea Seaqaqa Fiji
Type of Pulp Unbleached Sulphate
Type of Beater Valley

File No.
Cook No. K 398



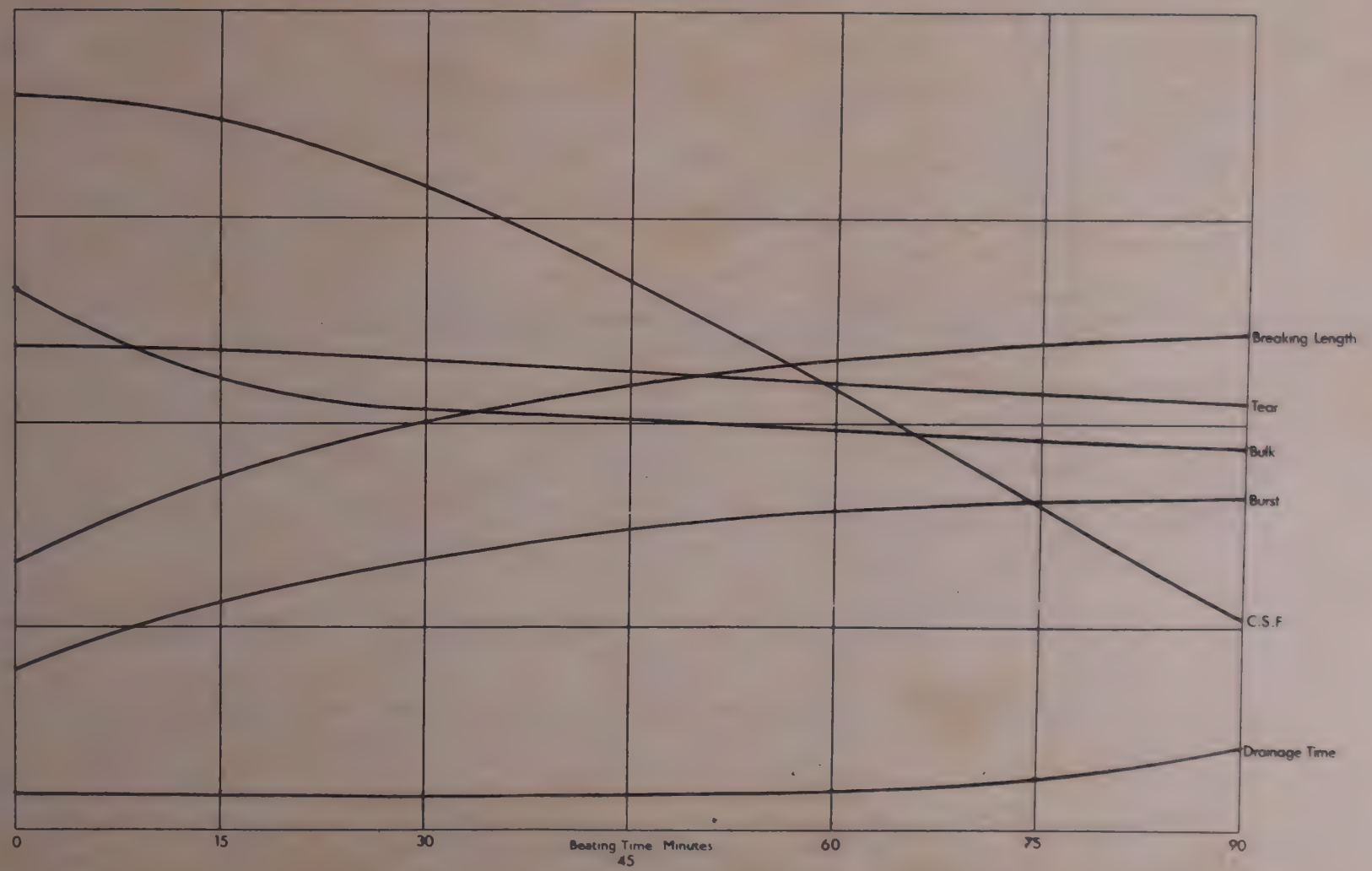
TROPICAL PRODUCTS INSTITUTE. LONDON . PULP & PAPER SECTION

PULP EVALUATION : BEATING CURVES

Raw Material Pinus caribaea Seaqaqa Fiji
Type of Pulp Unbleached Sulphate
Type of Beater Valley

File No
Cook No K 397

C S f ml	Drainage Time sec	Bulk ml/g	Burst Factor	Breaking Length, metres	Tear Factor
800	100	3 00	160	16000	300
600	75	2 25	120	12000	225
400	50	1 50	80	8000	150
200	25	0 75	40	4000	75
0	0	0	0	0	0



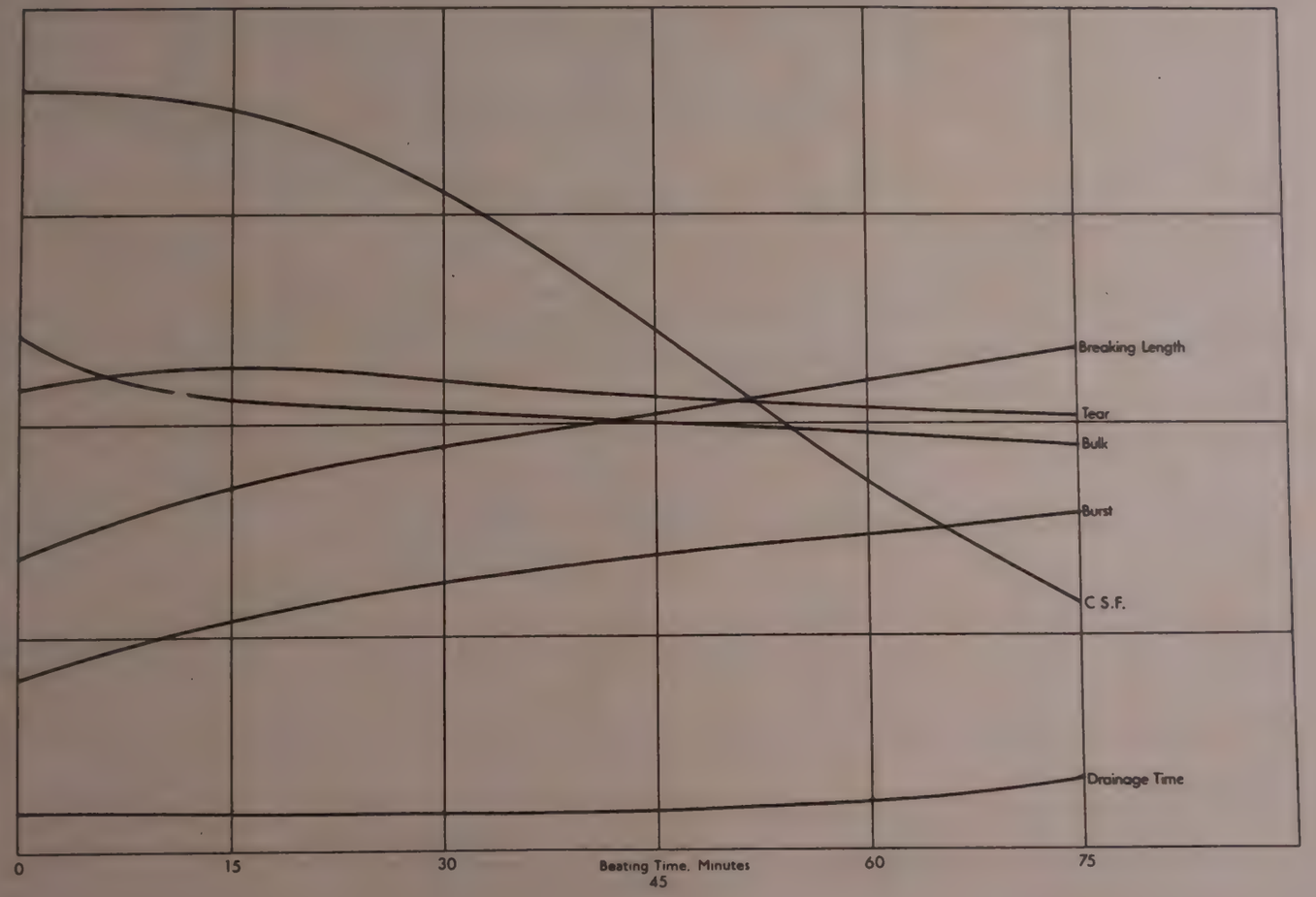
TROPICAL PRODUCTS INSTITUTE, LONDON . PULP & PAPER SECTION

PULP EVALUATION : BEATING CURVES

Raw Material Pinus caribaea Seaqaqa Fiji
Type of Pulp Unbleached Sulphate
Type of Beater Valley

File No.
Cook No. K 400

C.S.F. ml	Drainage Time, sec	Bulk, ml/g	Burst Factor	Breaking Length, metres	Tear Factor
800	100	3·00	160	16000	300
600	75	2·25	120	12000	225
400	50	1·50	80	8000	150
200	25	0·75	40	4000	75
0	0	0	0	0	0

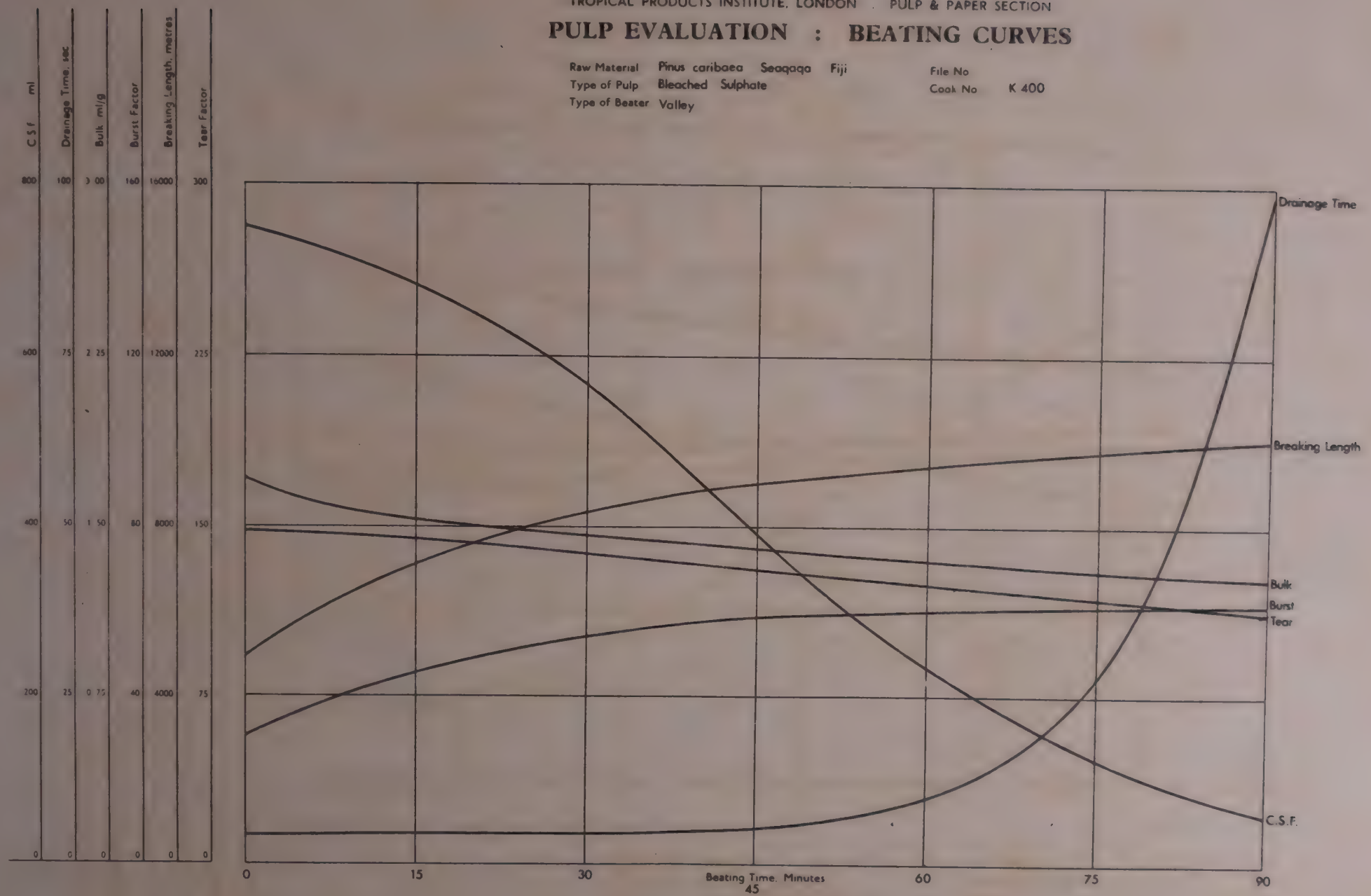


TROPICAL PRODUCTS INSTITUTE, LONDON . PULP & PAPER SECTION

PULP EVALUATION : BEATING CURVES

Raw Material Pinus caribaea Seaqaqa Fiji
Type of Pulp Bleached Sulphate
Type of Beater Valley

File No
Cook No K 400



MYSORE-2A

Tropical Products Institute

Pulping characteristics of nine-year old *Pinus caribaea* from Sabah

E. R. Palmer/J. A. Gibbs

Tropical Products Institute
56/62 Gray's Inn Road
London WC1X 8LU

Contents

	page
Summary	1
Principle characteristics of 9 year and 5 year old samples	2
Growing conditions and rate of growth	3
Physical examination	5
Fibre dimensions	5
Chemical analyses	7
Pulping trials	7
Pulp evaluation	7
Bleaching trials	8
Discussion of results of examination	8
Comparison with commercial pulpwoods	12
List of references	13

Tables:

P. caribaea from Sabah (9 year old sample)

1.	Bark Content and Wood Density	14
2.	Digestion conditions for sulphate pulps	15
3.	Unbleached sulphate pulp, beaten PFI mill	16
4.	Comparison of high and low density trees, unbleached sulphate pulp, beaten PFI mill	17
5.	Bleaching trials	18
6.	Bleached sulphate pulp, beaten PFI mill	19
7.	Evaluations from sulphate pulps	20
8.	Unbleached sulphate pulp evaluations of commercially used pulpwoods	21
9.	Comparative laboratory-made bleached sulphate pulps from commercial pulpwoods	22

Appendix:

Experimental methods in pulping investigations

1.	Apparent density of wood	1
2.	Bark: Wood ratio	
3.	Chemical analysis	
4.	Microscopic Examination	[2]
5.	Pulping methods	
6.	Unbleached pulp evaluation	3, 4

Pulping characteristics of nine-year old *Pinus caribaea* var *hondurensis* from Sabah

SUMMARY

The pulping characteristics of six trees of 9-year old *Pinus caribaea* var. *hondurensis*, representing a trial plantation in the Sibuga Forest Reserve, Sabah, were determined and compared with those determined earlier when the plantation was 5 years old, and with known commercial pulpwoods. The older wood was inferior to the younger in giving lower yields of pulp which had generally poorer strength properties except for tear. The older wood digested slightly more easily and it was more appropriate for making bleached pulp. Bleaching trials were therefore made, using about 10% available chlorine in a CEHD sequence, to give pulps with 75 to 76% brightness, and with rather low strength (because of the poor strength of the unbleached pulps, not because of loss during bleaching). Higher brightnesses should be obtainable with more elaborate techniques.

The trees with the highest and lowest densities were pulped separately, but little correlation was found between density and pulping characteristics. Compared with known pulpwoods this sample yielded pulps most resembling US Southern pine pulps, though a little weaker. Provided competition were not too fierce they could probably be used like Southern pine pulps, that is mainly for packaging papers (particularly liner boards for corrugated boxes) which are generally made in papermills integrated with the pulp mills. Relatively little Southern pine pulp is sold on the open market; some, semibleached, is exported to financially tied newsprint mills. Compared with Scandinavian type softwoods this *Pinus caribaea* gives pulps which are much weaker in burst and tensile strength and similar or slightly better in tearing strength.

The following Table highlights the changes due to the extra four years of growth.

Summary of Principal Characteristics of 9 year and 5 year Old Samples

Pulps with similar Kappa number are compared

Age of sample, years	9 years	5 years
Girth under bark, av. at breast height, mm	530	420
Wood density, dry wt/wet vol., kg/m^3	445	370
Bark % wood + bark, v/v	25	30
Alcohol-Benzene Extract %	0.9	3.5

Type of pulp	kraft		general purpose		Bleachable
	9 years	5 years	9 years	5 years	9 years
Kappa number	44	45	34	35	27
Sulphate digestion conditions					
Active alkali, Na_2O, added % wood	22.5	20	20	22.5	20
Temperature, °C	160	170	170	170	170
Time at temp., hours	4	3	3	4	4
Yield, OD, screened % wood	44.6	46.5	42.6	46.6	42.1

Physical properties of unbleached pulps:

Canadian Std. freeness	500	300	500	300	500	300	500	300	500	300
Bulk, ml/g	1.59	1.54	1.40	1.37	1.54	1.49	1.36	1.32	1.52	1.45
Burst Factor	52	57	62	70	48	51	57	63	44	47
Breaking Length, km	7.2	7.8	8.1	9.2	7.0	7.6	8.5	9.2	6.6	7.0
Tear Factor	175	160	140	130	140	125	130	125	120	110

Average dimensions of whole (unbroken) fibres in sulphate pulps:

	9 years	5 years
Length, mm	2.9	2.1
Width, apparent, nm	52	59
Wall Thickness, apparent, nm	5.1	5.5

INTRODUCTION

Pinus caribaea is one of a number of exotic species that have been planted in trial plots in the Sibuga Forest Reserve, Sabah. It was thought that paper pulp was a possible end use for this species. Accordingly, in 1964 samples of wood from the first plot established were sent to the Tropical Products Institute for evaluation: In the report[1] it was suggested that this young (five year old) sample would yield a pulp slightly weaker than a US Southern Pine pulp.

In 1967 a Feasibility Study of the Prospects of a Pulpwood Industry in Sabah was made. One conclusion was that it was not possible to make any definite recommendations on the feasibility or otherwise of a pulp industry until more information was available on the trial plantations in Sabah. It was recommended that the plantation programme should continue for the full rotation of the species under consideration before making any decision[2]. In order to assess the affect on pulp quality of four further years of growth, more samples from the same plot were sent to the Tropical Products Institute in 1969, and these samples are the subject of this report.

Growing Conditions and Rate of Growth

The samples came from Compartment 7L Sibuga Forest Reserve. The Sibuga Forest Reserve has been described by the Plantation Officer in The Malayan Forester[3]:

> "The topography can best be described as undulating. Ridges having an altitude ranging from sea level to about 40 feet above sea level are separated by gullies with a number of flat places which were levelled during pre-war years to serve as wet padi fields."
>
> "The geology is described as undivided Miocene of uncertain age and consists of sandstones, shales and occasional beds of quartz pebbles. The soil is a degraded red earth."
>
> "Very little if any of the original vegetation is to be found, but an area of 1½ acres (Plot 2D) of belukar is being left wild. Even in this area however there are some *Aleurites* and Oil palms, though there is no trace of seedlings of eight Dipterocarp species sown broadcast in 1963. Where the Forest Reserve has not been planted with trees, the ground is generally covered with lalang *(Imperata cylindrica)* except in the wet places where a sedge *(Cyperus elatus)* or the introduced Pata grass *(Pancium barbanoide)* grow strongly."
>
> "The mean annual rainfall is over 120 inches. The heavy rainfall comes with the north east monsoon (October to March), but seldom in any month is the rainfall less than 6 inches."

Pinus caribaea was planted in Compartment 7L in October 1959, using seed obtained from British Honduras and a spacing of 10 x 8 feet. The rate of growth has been determined by regular measurement; recent published results are given below[4].

Samples

Six trees of *Pinus caribaea* var. *hondurensis,* selected to be statistically representative of the site, were felled in April 1969; the age at this time was 9 years 6 months. Details of the girths of these six trees are given in Table 1. Their mean girth under bark at breast height was 2.02 feet (616 mm) which was below the average for the site of 2.19 feet (668 mm). Three logs each 2 feet 6 inches long, were cut from each tree with mid point heights of 4.5, 9.5 and 14.5 feet.

The density was determined on each log, but for all other determinations a composite sample of all logs was prepared.

Details of the experimental methods are given in an appendix.

Physical Examination

(a) Bark/Wood Ratio

The girths of the logs were measured both over and under bark. The ratio of the weight of dry bark to the weight of dry wood plus bark was determined by drying and weighing the bark from a measured length of log and calculating the weight of wood from its volume and density.

Table A

Date of Measurement	HEIGHT feet					GIRTH inches				
	Mean	Mean of Max 5	MAI		CAI	Mean	Mean of Max 5	MAI		CAI
			of Mean	of Max 5	of Mean / of Max 5			of Mean	of Max 5	of Mean / of Max 5
June 1964		44.7		9.5		17.4	25.0	3.7	5.3	3.1 / 4.2
June 1965		49.9		8.9	5.3	19.6	28.4	3.5	5.1	2.2 / 3.4
June 1966		56.0		8.4	6.1	22.1	31.9	3.3	4.8	2.4 / 3.5
June 1967		62.0		8.1	5.9	24.4	34.6	3.2	4.5	1.9 / 2.6
June 1968		62.8		7.2	0.8*	26.3	35.8	3.0	4.6	1.9 / 1.2

* The apparent sudden drop in height increment in 1968, as shown in the above table, appears to be the result of some anomalous measurements and should not be taken as representative of the height increment of the stand as a whole.

The full results for both determinations are given in Table 1; the mean values were 25 per cent of bark by volume, 12 per cent by weight. These values were a little lower than those found when younger wood was examined, but are higher than those normally found in temperate pulpwoods, for which Casey gives typical values as 15 per cent by volume, and 7 to 8 per cent by weight[6].

(b) Apparent Density

Values for the apparent density of the wood, expressed as oven dry weight/green (soaked) volume, are given in Table 1. In most cases the variation of density within the tree was not very large. The mean value was 445 kg/m^3 (27.8 lbs/ft^3), and the range between trees 385 kg/m^3 to 550 kg/m^3. There was not a direct relationship between rate of growth as indicated by girth and density; the most dense sample was the slowest grown, but the least dense was not the fastest grown.

The average density had increased from 370 kg/m^3 at five years to 445 at 9½ years. This probably reflects the decreasing rate of growth with increasing age.

The density is in the range of densities of pines used in the pulp industry.

Fibre Dimensions

The fibre dimensions were determined by measuring fibres dispersed from air dried standard sheets of a well cooked sulphate pulp, in an aqueous suspension. In report L12 on the 5 year sample measurements were made on fibres isolated in a different way. They have been redetermined on sulphate pulp as just described to make them comparable.

	Average Dimensions	
	9 year old sample	5 year old sample
Length of whole unbroken fibres only, mm	2.9	2.1
Length of all fibres, whole and broken, mm	2.3	1.8
Apparent fibre width, microns	52	59
Apparent fibre wall thickness, microns	5.1	5.5

The fibres of the older sample were longer but their width and wall thickness were less. The greater fibre length of the older sample was expected but it is difficult to explain the difference in width.

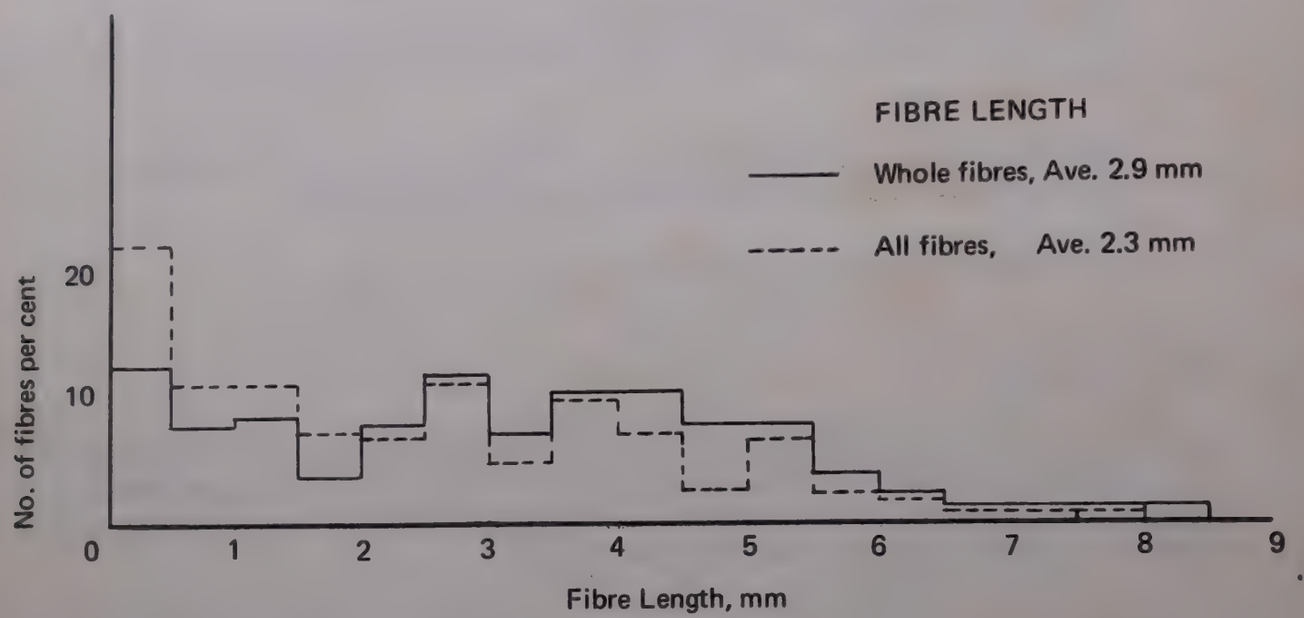
The histograms (Figure 1) show the range of values. The lengths ranged from less than 1 mm to over 7 mm with no dominant group; the widths ranged from 10 microns to 90 microns, but over 70 per cent were between 30 and 60 microns.

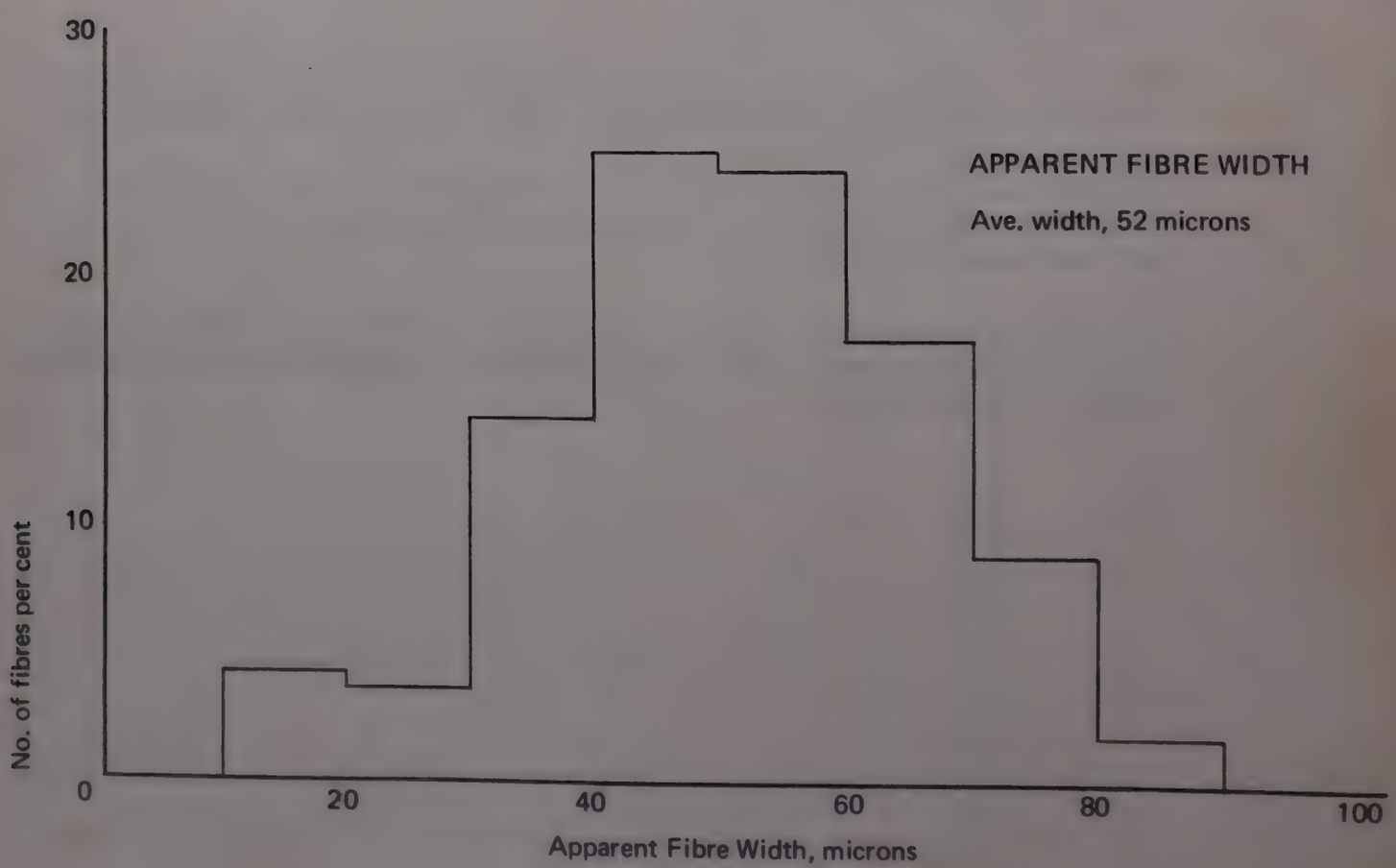
From these values it was expected that the pulps from this 9 year old sample would have similar bonding properties and possibly better tearing strength than the younger samples. Unfortunately this expectation was not fulfilled.

Figure 1

Pinus caribaea var. hondurensis from Sabah 9 years old
Fibre length and fibre width distribution

Samples derived from a standard sheet of well cooked sulphate pulp.





Chemical Analyses

The chemical analyses were carried out by standard methods using a ground portion of the bulk sample of chips.

	oven dry material as % oven dry wood	
	9 year old sample [a]	5 year old sample
Alcohol-benzene solubility	0.9	3.5
Holocellulose, dry	59.8	61[b]
Alpha-cellulose	40.9	40.3
1% NaOH solubility	12.6	9.8
Lignin	28.4	–

a. determined about one year after the tree was felled.

b. the figure originally reported as air dry holocellulose on oven dry (OD) wood has been modified to approximate OD holocellulose on OD wood an allowance for estimated moisture content being made.

Apart from the very low alcohol benzene solubility of the 9 year old sample, there were no significant differences. The alcohol-benzene solubility of this sample was the lowest we have found in *P. caribaea*.

The other values were not exceptional. No difficulty was expected or found in sulphate pulping.

Pulping Trials

Details of digestion conditions are given in Table 2.

A series of sulphate digestions were made on a bulk sample representative of the site. The active alkali, digestion temperature and time of digestion were varied to give a range of pulps with Kappa numbers from 44 (as might be required for kraft packaging papers) to 24 (as might be required for bleaching).

The yield of pulp was almost directly related to the Kappa number: from 40 per cent for bleachable pulps to about 46 per cent for those least severely treated.

In addition trees 4 and 6, with the lowest and highest density, were each pulped individually using conditions almost identical with those for the bulk sample.

Pulp Evaluation

All of the unbleached pulps were evaluated by beating in a PFI mill, preparing sheets by the British Standard method and testing the physical properties of the sheets at 20°C and 65% relative humidity. The results are given in full in Table 3, illustrated in the attached beating curves and, for ease of comparison, values at 500 and 300 Canadian Standard Freeness are given in Table 7.

The pulps were all of moderate strength only. Much the strongest was obtained with a longer cook at a lower temperature. It should not be inferred that these particular conditions are the only ones for best strength, but before projecting a commercial digester it would be important to determine, by means of further trials, the optimum conditions within the parameters for that digester.

The results of the evaluation of the pulps from the least and most dense trees are given in Tables 4 and 7. The pulp from the most dense tree was more bulky and had a higher tearing strength; there was no significant difference in other strength properties. The pulps from both the individual trees were marginally weaker in all strength properties except tear, than pulps of equal Kappa numbers from the bulk sample. It was concluded that there was no useful correlation between wood density and pulping properties.

Bleaching Trials

The two pulps with the lowest Kappa numbers (ie. lowest lignin contents) were bleached using a four stage sequence of chlorination, alkaline extraction, hypochlorite bleach and chlorine dioxide.

Details of the bleaching conditions are given in Table 5. The full evaluation of the bleached pulps is in Table 6 and at 500 and 300 CSf in Table 7.

The pulp with a Kappa number of 27.0, required the addition of a total of 11.1% chlorine to yield a pulp with a brightness of 75 (Elrepho 457 nm filter, brightness of MgO = 100); that with a Kappa number of 23.9 the addition of 10.1% chlorine to give a pulp with brightness of 76. These results are similar to those we have obtained with samples of *P. caribaea* from other sources but 5 or 6 points lower than with *Pinus sylvestris* and Southern pines. (See table 9). More elaborate bleaching could give higher brightness.

Of the optical properties, the printing opacity was measured on sheets with a substance approximately 600 g/m^2 and is only valid for sheets of this substance; the specific scattering coefficient depends solely on the fibre and the pulping method and can be used to calculate the printing opacity of sheets of any substance[6]. Rydholm[7] states that the specific scattering coefficient for commercial pine bleached kraft pulps is between 185 and 210 for pulps at 500 Canadian Standard Freeness and between 150 and 185 for pulps at 250 CSf. The values for both of the bleached pulps from Sabah *P. caribaea* were lower. Had the pulp not been air dried before it was made into sheets the results might have been lower still[8].

The strength of the bleached pulps was low, but this was due to the low strength of the unbleached pulps, not to loss of strength during bleaching.

If the manufacture of bleached pulp is under consideration a more thorough investigation is required, but the present results suggest that this material is likely to be suitable only for lower grades of bleached pulp.

Discussion

The full results of the examination of the 5 year old sample are given in TPI Report L12/1967, but some of the results are repeated here. The major differences have been summarised earlier in the report.

Both samples were digested using the same digester and digestion conditions except for the amount of active alkali with the following results.

	5 year old sample		9 year old sample	
Density of wood, kg/m^3	375		445	
Active Alkali % dry wood	20	22.5	17.5	20
Yield of digested pulp %	45.5	46.8	43.4	42.3
Yield of screened pulp %	45.0	46.6	42.6	42.1
Kappa No of Screened Pulp	40	35	40	27

The older sample could be digested to the same Kappa number (residual lignin content) as the younger using slightly milder conditions, but the yield of pulp from the older sample was lower. The lower resin content (alcohol-benzene solubles) of the older sample might explain the greater ease of pulping, but not the lower yields. Because it digested more readily bleachable pulp was prepared from the older sample.

Figure 2

Comparison of 5 and 9 year old Pinus caribaea from Sabah—strength of pulp at about 34 Kappa number

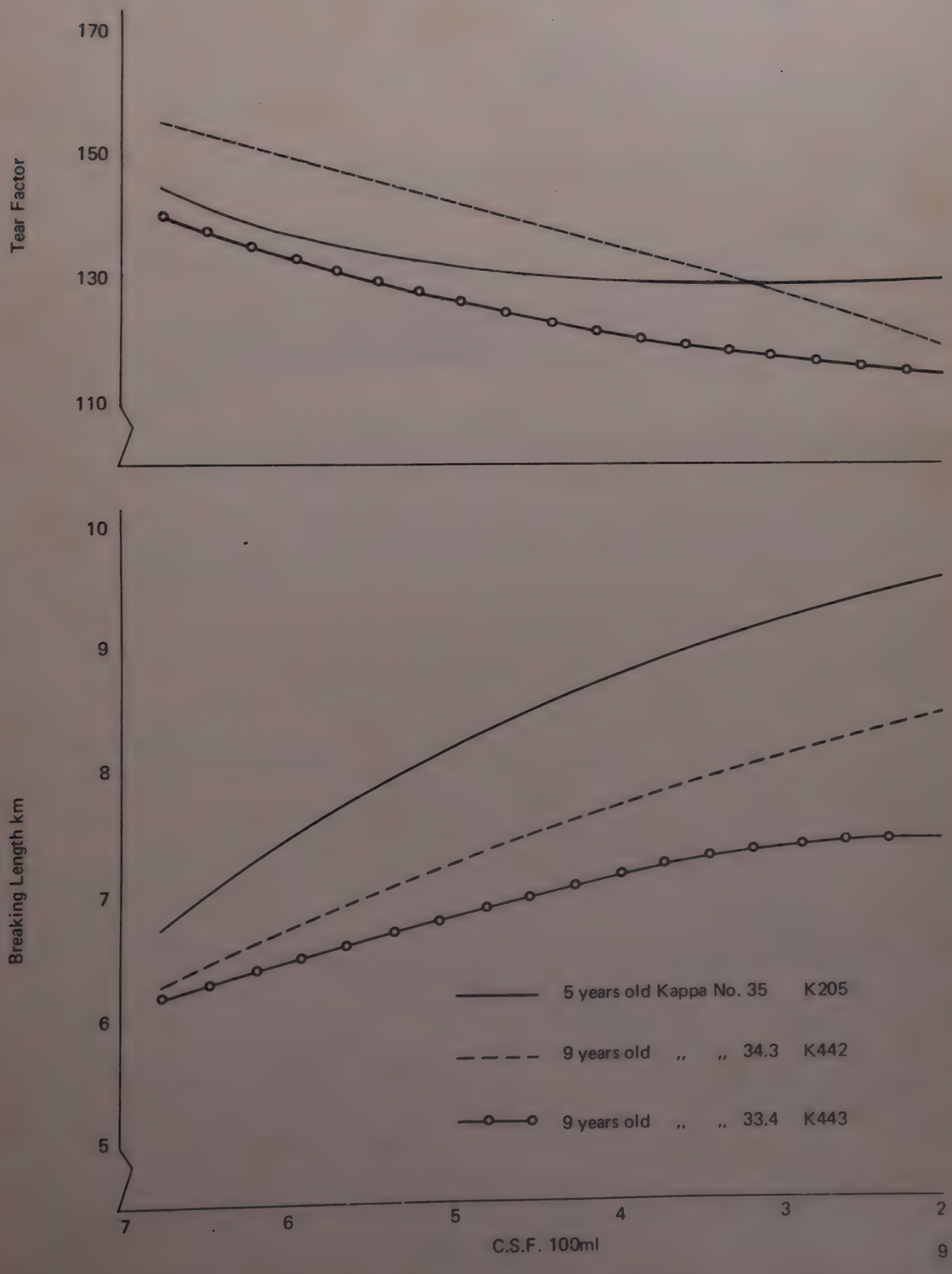
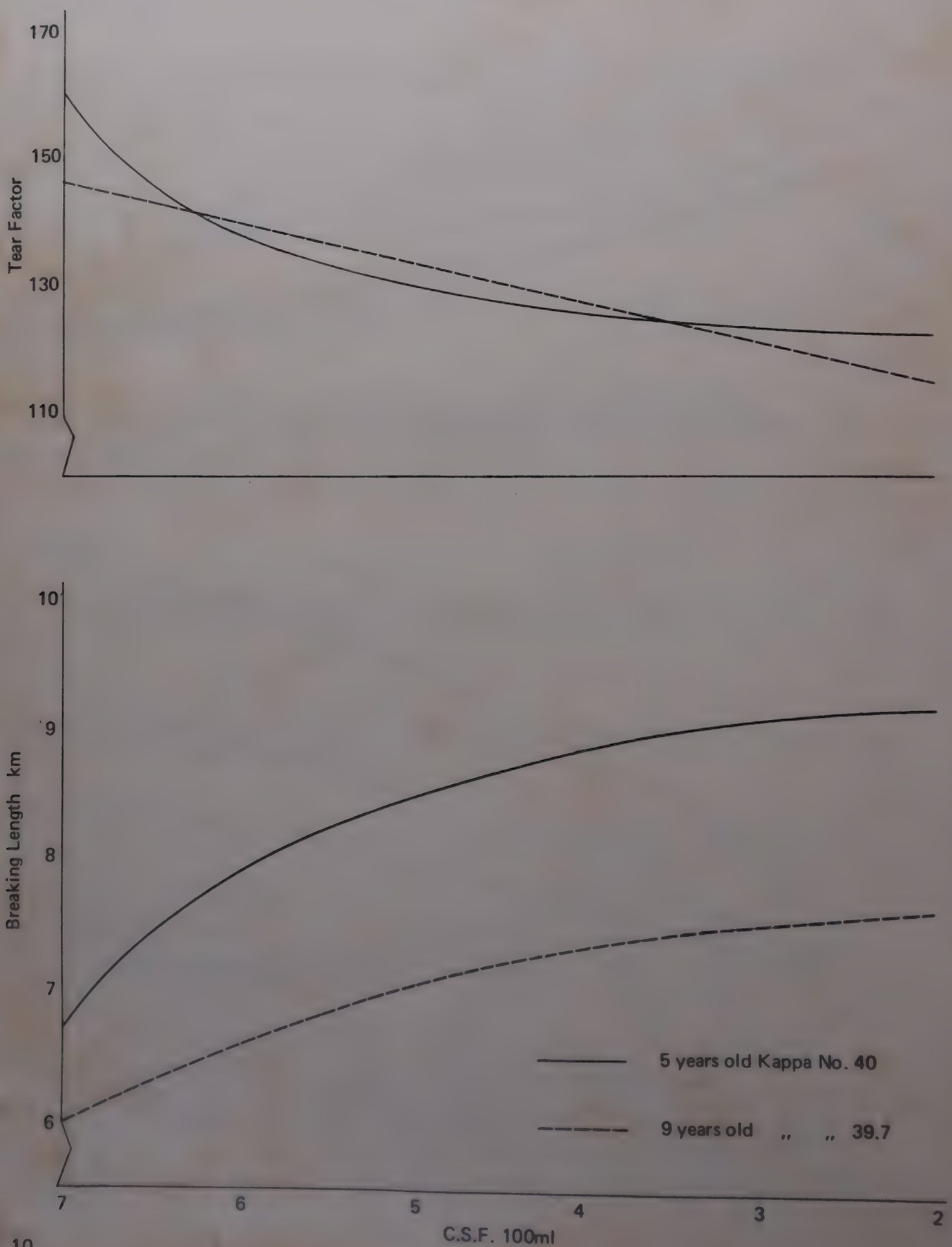


Figure 3

Comparison of 5 and 9 year old Pinus caribaea from Sabah—strength of pulp at about 40 Kappa number



Comparison of pulp strengths at two approximately equal Kappa numbers are shown in figures 2 and 3. Two factors have been selected for these comparisons: breaking length (a numerical value for the tensile strength) to illustrate a strength factor more dependent on fibre to fibre bonding than on fibre strength, and tearing strength for a factor in which fibre strength is more important. The breaking length of pulp from older samples was always more than 10% less than from younger samples. The differences in tearing strength were smaller, rarely as much as 10%, and not consistently in favour of either.

If *P. caribaea* similar to these samples is to be used commercially for the production of pulp, then the period of rotation and the type of pulp to be produced require careful study. Overall economy is affected by factors seen in this report such as:

a. the reduction in volume increment which has occurred between 5 and 9 years.

b. the lower yield of pulp per ton of dry wood at 9 years.

c. the higher density of the 9 year old wood, which is an advantage for transport and for packing the digester,

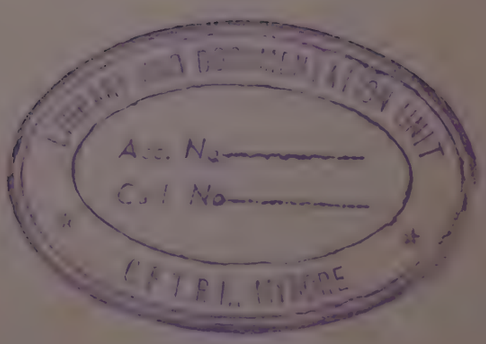
d. the older samples required slightly less alkali or milder conditions for cooking (but the pulps had overall poorer strength).

Comparison with Commercial Pulpwoods

In order to assess the value of potential pulpwoods, a number of established pulpwoods have been pulped in this laboratory under conditions similar to those described to provide a basis for comparison. The results and pulp yield at various Kappa numbers of pulp strengths at 500 and 300 CSf are given in Table 8.

The yield of pulp from 9 year old *P. caribaea* was 1 to 2% lower than for these pulpwoods at equal Kappa number. The strength of the *P. caribaea* pulps were lower than those from established pulpwoods, but approached nearer to USA Southern Pines than the others.

It is likely that pulps from *P. caribaea* could be used in much the same way as Southern Pine, that is for packaging papers in an integrated pulp and paper mill, but if this sample is typical it is not a very desirable pulpwood.



REFERENCES

1. E. R. PALMER, J. A. GIBBS, The Pulping Characteristics of *Pinus caribaea* from Sabah, TPI Report L12, 1967.
2. Forest Dept. Sabah, 1968 Annual Report, Research Branch.
3. J. F. POLLARD, Sibuga Forest Reserve, Sabah, *Malayan Forester*, 1968, XXXI, 365.
4. Forest Department, Sabah, Research programme 1960-64, 1964, Supplement and Final Report.

   Forest Department Sabah, Annual Report, Research Branch, 1965.
   " " " " " " " 1966.
   " " " " " " " 1967.
   " " " " " " " 1968.

5. J. P. CASEY, Pulp and Paper Chemistry and Chemical Technology, Volume 1, Pulping and Bleaching, p.75. Interscience Publishers, New York and London, 1960.
6. H. W. GIERTZ, Opaciteten Lost Pappersmassor, *Svensk Papperstidning,* 1950, 53, 673.
7. S. A. RYDHOLM, Pulping Processes, p.856. Interscience Publishers, New York, 1965.
8. Ref 7, p.854.

Tables

Table 1

***Pinus caribaea* from Sabah**

9 year old sample

Bark content and wood density

Tree/log Number	Height of midpoint of log, feet	Girth, cms		Bark/Wood plus bark		Density of Wood Dry wt/green vol	
		Overbark *	Underbark	by volume %	by weight (dry) %	kg/m^3	lbs/ft^3
1/1	4.5	61.0	53.3	24	14	450	28.1
1/2	9.5		50.8		12	385	24.1
1/3	14.5		46.4		10	420	26.3
Ave Tree 1					12	425	26.5
2/1	4.5	61.0	49.5	34	17	510	31.8
2/2	9.5		49.5		17	440	27.4
2/3	14.5		45.7		16	440	27.4
Ave Tree 2					17	465	29.0
3/1	4.5	71.8	63.5	22	13	510	31.8
3/2	9.5		44.4		14	365	22.8
3/3	14.5		40.6		12	505	31.4
Ave Tree 3					13	475	29.6
4/1	4.5	64.8	55.9	26	14	380	23.6
4/2	9.5		53.5		10	395	24.7
4/3	14.5		47.0		10	375	23.3
Ave Tree 4					12	385	23.9
5/1	4.5	58.4	50.8	24	10	450	28.0
5/2	9.5		48.3		14	400	24.8
5/3	14.5		44.4		10	425	26.4
Ave Tree 5					11	425	26.5
6/1	4.5	51.4	45.7	21	11	550	34.3
6/2	9.5		40.6		10	560	34.9
6/3	14.5		36.8		10	535	33.5
Ave Tree 6					11	550	34.3
Grand Average for site		61.6*	53.1*	25	12	445	27.8
Ave for 5 year old sample			42.3*	30	15	370	22.8

* at breast height (4.5 feet)

Table 2

9 year old *Pinus caribaea* from Sabah

Digestion conditions for sulphate pulps

Cook number	K437	K436	K442	K443	K434	K435	K438	K439
Sample	Bulk	Bulk	Bulk	Bulk	Bulk	Bulk	Tree 4 385 kg/m^3	Tree 6 550 kg/m^3
Active Alkali as Na_2O% on oven dry wood	22.5	17.5	20	22.5	20	21.25	17.5	17.5
Sulphidity	25	25	25	25	25	25	25	25
Liquor (including moisture) to oven dry wood ratio, litres/kg	6:1	6:1	6:1	6:1	6:1	6:1	6:1	6:1
Maximum temperature °C	160	170	170	160	170	170	170	170
Time from about 20°C to maximum temperature, hours	1	1	1	1	1	1	1	1
Time at maximum temperature, hours	4	4	3	5	4	4	4	4
Active Alkali consumed as Na_2O% oven dry wood	12.0	13.8	14.2	15.0	14.2	14.6	13.3	13.8
Yield, oven dry digested pulp % oven dry wood	45.9	43.4	43.3	43.8	42.3	40.7	43.5	46.4
Screening on 0.15 mm slots: Rejects, oven dry rejects % oven dry pulp	2.7	2.0	1.6	0.7	0.5	0.4	1.4	2.4
Yield, oven dry screened pulp % oven dry wood	44.6	42.6	42.6	43.5	42.1	40.5	42.8	45.3
Kappa number of screened pulp	44.2	39.7	34.3	33.4	27.0	23.9	34.4	34.6

Table 3

Pinus caribaea **from Sabah**
9 year old sample
Unbleached sulphate pulp
Beaten: P.F.I. mill

Cook number	Beating Time mins	Canadian Standard freeness	Drainage Time Secs	Basis Weight g/m^2	Air Porosity 100 ml/in^2 secs	Thickness microns	Bulk cm^3/g	Burst Factor	Breaking Length metres	Stretch per cent	Tear Factor	Double Folds Kohler-Molin 800g
K437	0	770	4.3	60.6	0.1	155	2.563	16.2	3038	2.7	181	37
Active Alkali 22.5	1	760	4.4	60.0	0.3	107	1.789	31.2	5036	4.7	200	1093
Digestion Temp. 160°C	2	720	4.4	59.3	0.8	101	1.697	38.6	5943	4.6	183	2058
Digestion Time 1+4 hrs	3	650	4.6	60.2	1.4	100	1.658	46.2	6774	4.2	189	2640
Yield of Screened Pulp 44.6%	4	565	4.6	58.6	5.6	94	1.596	50.8	7113	4.1	167	2863
Kappa Number 44.2	6	320	5.0	57.9	89.1	90	1.550	56.4	7736	4.1	167	3041
	8	185	6.5	58.4	647.3	86	1.463	58.8	8351	4.4	150	3395
K436	0	760	4.5	60.1	0.1	219	3.641	8.9	1919	2.3	118	4
Active Alkali 17.5	1	740	4.4	58.9	0.5	103	1.748	32.3	5193	4.9	155	582
Digestion Temp. 170°C	2	690	4.6	59.3	1.0	104	1.746	40.5	6073	4.6	143	1718
Digestion Time 1+4 hrs	3	580	4.6	58.7	6.0	96	1.645	46.0	6740	4.3	142	1807
Yield of Screened Pulp 42.6%	4	445	4.8	58.7	18.6	95	1.616	49.7	7137	4.5	135	1694
Kappa Number 39.7	6	250	6.0	58.3	299.0	90	1.535	53.8	7670	4.2	115	2053
	8	120	11.0	58.1	over 1000	83	1.424	55.1	8237	3.9	112	3148
K442	0	760	4.4	61.8	0.2	148	2.489	14.0	2665	3.2	143	16
Active Alkali 20	1	730	4.5	58.5	0.6	100	1.718	34.0	5338	4.7	170	942
Digestion Temp. 170°C	2	680	4.6	61.5	1.2	99	1.612	41.2	6215	5.0	157	1306
Digestion Time 1+3 hrs	3	580	4.5	59.6	4.9	95	1.594	43.0	6732	4.0	147	1651
Yield of Screened Pulp 42.6%	4	460	4.6	59.2	15.4	91	1.543	49.2	6951	4.8	142	1578
Kappa Number 34.3	5	330	5.4	60.5	91.6	89	1.466	50.9	7336	4.5	131	2064
	6	230	6.2	58.2	299.7	86	1.468	52.7	7863	4.4	118	2084
	8	110	14.3	59.0	over 1000	83	1.406	55.3	8553	4.1	119	2442

Table 3 (continued)

***Pinus caribaea* from Sabah**
9 year old sample
Unbleached sulphate pulp

Beaten: P.F.I. mill

Cook number	Beating Time mins	Canadian Standard freeness	Drainage Time Secs	Basis Weight g/m^2	Air Porosity 100 ml/in^2 secs	Thickness microns	Bulk cm^3/g	Burst Factor	Breaking Length metres	Stretch per cent	Tear Factor	Double Folds Kohler-Molin 800g
K443	0	760	4.2	58.8	0.1	148	2.526	12.6	2547	2.8	127	11
Active Alkali 22.5	1	740	4.4	59.8	0.4	105	1.761	31.0	5063	4.8	156	440
Digestion Temp. 160°C	2	680	4.4	59.0	1.1	96	1.622	38.7	6155	4.2	140	1155
Digestion Time 1+5 hrs	3	585	4.5	60.7	3.3	97	1.591	41.5	6545	4.0	132	1851
Yield of Screened Pulp 43.5%	4	450	4.8	59.4	11.0	93	1.563	45.1	7041	4.3	124	1183
Kappa Number 33.4	5	375	5.0	60.6	34.2	91	1.502	45.3	6733	4.8	123	1298
	6	240	6.0	59.0	248.3	87	1.478	48.6	7316	3.8	114	1492
	8	120	12.3	57.9	over 1000	85	1.472	56.0	8259	3.7	101	2195
K434	0	755	4.4	60.9	0.1	163	2.676	10.7	2285	2.3	119	9
Active Alkali 20	1	750	4.4	58.7	0.6	100	1.701	30.5	5035	4.7	140	315
Digestion Temp. 170°C	2	670	4.5	59.2	1.9	95	1.608	39.7	6005	3.7	132	1025
Digestion Time 1+4 hrs	3	540	4.7	59.2	10.1	91	1.533	40.0	6319	4.4	121	1022
Yield of Screened Pulp 42.1%	4	380	5.0	60.2	68.8	88	1.459	45.3	6815	4.0	114	1173
Kappa Number 27.0	6	190	7.4	58.4	over 1000	82	1.403	47.9	7522	3.9	104	1719
	8	95	25.1	59.4	over 1000	78	1.319	49.2	8138	3.8	97	2062
K435	0	760	4.4	58.6	0.1	166	2.830	9.4	2031	4.0	126	8
Active Alkali 21.25	2	640	4.6	59.8	2.1	95	1.596	35.4	5817	3.9	112	505
Digestion Temp. 170°C	3	435	5.0	59.4	23.6	94	1.582	39.9	6343	3.8	100	680
Digestion Time 1+4 hrs	4	320	5.6	59.6	203.8	85	1.427	41.2	6817	4.1	97	860
Yield of Screened Pulp 40.5%	6	140	14.4	59.3	over 1000	82	1.385	44.7	7440	3.8	98	1105
Kappa Number 23.9	8	60	49.0	58.2		75	1.292	47.3	7612	3.8	99	1336

Table 4

Pinus caribaea **from Sabah**

9 year old sample

Comparison of high and low density trees

Unbleached sulphate pulp

Beaten: P.F.I. mill

Tree Number	Density kg/m^3	Cook Number	Beating Time mins	Canadian Standard freeness	Drainage Time Secs	Basis Weight g/m^2	Air Porosity 100 ml/in^2 secs	Thickness microns	Bulk cm^3/g	Burst Factor	Breaking Length metres	Stretch per cent	Tear Factor	Double Folds Kohler-Molin 800g
		K438												
4	385	Active Alkali 17.5	0	755	4.4	61.7	0.2	160	2.600	10.6	1835	3.3	139	7
		Digestion Temp. 170°C	1	700	4.6	59.7	0.7	104	1.738	30.4	4667	4.9	146	428
		Digestion Time 1+4 hrs	2	685	4.6	59.8	2.4	96	1.610	38.3	5752	4.2	129	992
		Yield of Screened												
		Pulp 42.8%	3	615	4.7	57.0	7.1	89	1.568	41.8	6260	3.9	117	807
		Kappa Number 34.4	4	500	5.0	59.3	21.4	90	1.515	44.4	6675	4.6	99	1091
			6	240	6.3	58.7	530.5	84	1.440	47.0	7353	4.5	92	1317
			8	85	14.8	58.5	over 1000	83	1.423	49.6	7470	4.2	99	2010
		K439												
6	550	Active Alkali 17.5	0	760	4.4	62.2	0.1	182	2.935	6.2	1226	1.1	108	2
		Digestion Temp. 170°C	1	770	4.4	60.5	0.2	111	1.838	25.2	4492	3.9	146	161
		Digestion Time 1+4 hrs	2	690	4.5	60.5	0.5	104	1.718	34.9	5858	4.3	143	560
		Yield of Screened												
		Pulp 45.3%	3	615	4.6	59.6	1.4	101	1.695	39.9	6110	4.0	147	861
		Kappa Number 34.6	4	480	4.7	58.7	6.1	95	1.623	43.1	6325	3.8	133	1072
			6	200	6.2	59.7	228.3	90	1.514	49.9	7231	4.3	123	2027
			8	90	15.0	57.5	over 1000	84	1.456	54.3	7912	3.7	120	2426

Table 5

Pinus caribaea from Sabah

9-year old sample

Bleaching Trials

Cook Number	K434	K435
Kappa Number of unbleached pulp	27.0	23.9
Chlorination		
Pulp consistency, %	3	3
Temperature, °C	20	20
Time, hours	1	1
Chlorine added on oven dry, pulp, %	7.5	6.5
Chlorine consumed on oven dry pulp, %	6.7	5.8
Alkali Extraction		
Pulp consistency, %	6	6
Temperature, °C	60	60
Time, hours	1	1
NaOH on oven dry pulp, %	3	3
Hypochlorite Bleach		
Pulp consistency, %	6	6
Temperature, °C	35	35
Time, hours	2	2
Active chlorine added on oven dry pulp, %	1.0	1.0
Active chlorine consumed on oven dry pulp, %	0.94	0.97
Chlorine Dioxide Bleach		
Pulp consistency, %	6	6
Temperature, °C	70	70
Time, hours	3	3
ClO_2 added on oven dry pulp, %	1	1
ClO_2 added as equivalent available chlorine on oven dry pulp, %	2.6	2.6
ClO_2 consumed on oven dry pulp, %	0.9	0.9
As equivalent available chlorine consumed on oven dry pulp, %	2.3	2.3
Total chlorine added, %	11.1	10.1
Total chlorine consumed, %	10.0	9.1
Yield, oven dry bleached pulp, % oven dry unbleached pulp	95.7	95.9
oven dry bleached pulp, % oven dry wood	40.3	38.8
Brightness, Elrepho 457 nm Filter, MgO = 100	75	76

Table 6

Pinus caribaea **from Sabah**

9-year old sample
Bleached sulphate Pulp

Beaten: P.F.I. mill

Cook Number	Kappa Number	Total Chlorine per cent pulp added	used	Beating Time, min	Canadian Standard freeness	Drainage Time, secs	Basis Weight, g/m^2	Air Porosity 100ml/in^2 secs	Thick-ness, microns	Bulk, cm^3/g	Burst Factor	Break-ing Length, metres	Stretch, per cent	Tear Factor	Double Folds, Kohler Molin 800g	Bright-ness, 457 nm filter Elrepho, %MgO	Reflect-ance tristimu-lus, green (Y) filter, %MgO	Printing Opacity, green (Y) filter	Specific Scattering Coeffi-cient, green (Y) filter
K434	27.0	11.0	10.0	0	750	4.4	59.6	0.2	140	2.35	12.6	2060	3.6	133	12	75	85	77	340
				1	740	4.4	59.8	0.8	101	1.68	30.6	4765	4.8	145	320		81	68	215
				2	660	4.5	59.2	1.9	96	1.61	38.2	5886	4.7	125	756		80	64	185
				3	545	4.7	57.8	9.8	88	1.53	42.5	6506	4.2	112	1093		78	61	165
				4	400	5.0	58.2	76.1	86	1.48	44.5	6787	4.3	109	1125		77	60	155
				6	165	9.2	58.2	over 1000	82	1.40	48.2	7617	4.2	100	1471		75	57	135
K435	23.9	10.0	9.1	0	750	4.4	64.1	0.2	160	2.50	12.2	2117	3.4	145	12	76	86	79	350
				1	710	4.5	59.1	1.0	102	1.72	27.1	4653	4.8	117	117		82	69	230
				2	625	4.6	58.1	3.8	96	1.65	34.5	5436	4.2	110	352		81	64	195
				3	450	4.9	59.5	25.0	92	1.55	37.9	6090	4.1	96	358		80	62	170
				4	300	5.6	58.3	196.2	87	1.49	40.4	6437	3.9	89	473		79	60	160
				6	105	18.1	58.5	over 1000	81	1.38	43.7	7161	3.7	78	753		75	56	130

Table 7

9 year old *Pinus caribaea* from Sabah. Evaluations of sulphate pulps.

Cook No.	Act. Alk. %	Temp. °C	Time at temp. hrs	Scrd. Yield %	Kappa No.	CSf	Bulk cm^3/g	Burst Factor	Breaking Length metres	Tear Factor
Nine years old sample. Beaten in P.F.I. mill										
K437	22.5	160	4	44.6	44.2	500	1.59	52	7200	175
						300	1.54	57	7800	160
K436	17.5	170	4	42.6	39.7	500	1.61	48	7000	135
						300	1.56	53	7600	120
K442	20.0	170	3	42.6	34.3	500	1.54	48	7000	140
						300	1.49	51	7600	125
K443	22.5	160	5	43.5	33.4	500	1.56	45	7000	130
						300	1.51	49	7400	115
K434	20.0	170	4	42.1	27.0	500	1.52	44	6600	120
						300	1.45	47	7000	110
K435	21.25	170	4	40.5	23.9	500	1.51	38	6300	105
						300	1.43	42	6800	100
Lowest density tree										
K438	17.5	170	4	42.8	34.4	500	1.52	45	6700	105
						300	1.47	47	7100	95
Highest density tree										
K439	17.5	170	4	45.3	34.6	500	1.62	43	6600	135
						300	1.56	46	7000	125
K434 Bleached, Brightness				75		500	1.53	42	6800	115
						300	1.46	45	7200	105
K435 Bleached, Brightness				76		500	1.59	38	6000	100
						300	1.50	40	6600	90
Five years old sample. Beaten in Valley Beater (from report L12)										
K200	17.5	170	3	49.2	58	500	1.37	65	8800	135
						300	1.35	71	9350	127
K199	20.0	170	3	46.5	45	500	1.40	62	8100	140
						300	1.37	70	9200	130
K204	20.0	170	4	45.0	40	500	1.36	62	8100	130
						300	1.30	68	9300	125
K205	22.5	170	4	46.6	35	500	1.36	57	8500	130
						300	1.32	63	9200	125

Table 8

Unbleached Sulphate Pulp Evaluations of Commercially Used Pulpwoods

Values at 500 and 300 CSf

Species	Kappa Number	Yield of unbleached pulp % O D Wood		Canadian Standard freeness	Bulk cm^3/g	Burst Factor	Breaking Length metres	Tear Factor
		Total	Screened					
Pinus sylvestris	72.4	52.7	46.7	500	1.57	64	9200	175
UK grown				300	1.50	69	9800	155
	54.6	48.1	45.8	500	1.50	75	10400	165
				300	1.48	79	10900	155
	36.0	45.5	45.2	500	1.47	70	10000	165
				300	1.40	74	10500	155
	27.2	43.4	43.4	500	1.49	62	9400	165
				300	1.44	67	10100	155
Mixed Southern Pines	52.3	49.0	48.5	500	1.60	61	8600	175
USA grown				300	1.53	67	9500	165
	40.8	45.5	45.1	500	1.53	60	8500	185
				300	1.50	64	9000	175
	22.6	43.7	43.2	500	1.59	41	7000	100
				300	1.53	44	7400	90
Picea sitchensis	54.0	50.7	48.6	500	1.32	79	11200	110
UK grown				300	1.27	82	11600	105
	33.0	44.3	43.9	500	1.40	59	9100	95
				300	1.35	64	10000	85
	22.3	42.6	42.4	500	1.39	50	8100	80
				300	1.34	54	8900	75
Spruce	87.2	56.4	54.8	500	1.36	94	12800	115
USA grown				300	1.32	100	13000	100
	55.6	50.7	50.3	500	1.44	83	11450	140
				300	1.38	92	12400	130
	23.2	43.5	43.5	500	1.35	56	9100	90
				300	1.30	60	9600	85

Table 9

Comparative laboratory-made bleached sulphate pulps from commercial pulpwoods

Bleaching stages: C-E-H-D

Physical characteristics interpolated at 500 and 300 CSf

Country of Origin and Species	Kappa Number of Unbleached Pulp	Yield of Oven-dry Bleached Pulp, per cent oven-dry wood	Brightness (unbeaten), Elrepho 457 nm, per cent	Canadian Standard freeness	Bulk cm^3/g	Burst Factor	Breaking Length, metres	Tear Factor	Specific Scattering Coefficient
UK, *Pinus sylvestris*	27	41.4	81	500	1.43	60	9100	162	205
				300	1.39	67	9900	147	180
USA, Southern Pines	24	42.0	82	500	1.50	48	7700	150	175
				300	1.46	51	8100	136	164

Appendices

APPENDIX

Experimental Methods in Pulping Investigations

(1) *Apparent density of wood*

The method used was TAPPI Standard method T 18m-53[1] using one piece approximately one inch thick from each log received.

The green volume was determined by weighing the disc, which had been soaked in water until it was saturated, immersed in water. The oven-dry weight was determined by weighing the disc after it had been dried to constant weight at $105^{o} \pm 3^{o}C$.

The apparent density is expressed as: $\frac{\text{oven-dry weight}}{\text{Green (soaked volume)}}$

(2) *Bark: Wood ratio*

The percentage of bark in the total trunk (i.e. wood plus Bark) was determined both by volume and weight.

The volumetric determination was by measuring the girth over and underbark and the length of the log and calculating the percentage bark from $\frac{(g_o^2 - g_u^2)\ 100}{g_o^2}$

Where g_o = girth overbark
g_u = girth underbark

The gravimetric determination was by drying at $105^{o}C$ and weighing the bark from a measured length of log and calculating the dry weight of wood from its volume and density. Then percentage of bark by weight = (Wood/Wood plus bark) x 100.

(3) *Chemical analysis*

The chemical analyses were carried out on a composite sample. A portion of the chips prepared for pulping trials was ground in an Apex knife mill and the fraction of groundwood which passed through a British Standard 40 mesh (420 microns) sieve and was retained on a British Standard mesh (250 microns) sieve used for analysis.

The methods used were:

Alcohol benzene solubility	TAPPI T 6m-59[1]
Holocellulose	Wise, Murphy, D'Addieco[2]
Alpha-cellulose	TAPPI T203 os-61[1]
1% Caustic Soda Solubility	TAPPI T 4m-59[1]
Lignin	TAPPI T 13m-54[1]

The fractions soluble in alcohol-benzene and 1% caustic soda are expressed as oven dry extractives per cent oven-dry wood.

The alpha-cellulose and lignin are expressed oven dry per cent oven dry wood.

The holocellulose cellulose was dried by washing in acetone and storing at room temperature in a desiccator until constant weight. Under these conditions the holocellulose was found to have a moisture content of 2 per cent. In calculating the result allowance was made for this moisture content and the result is reported as oven dry holocellulose per cent over dry wood.

(4) *Microscopic Examination*

The fibre measurements were made on re-dispersions of pieces of standard sheets made fom unbeaten sulphate pulp and they are thus representative of a composite sample. The fibres were mounted in aqueous medium and the length, width and wall thickness of 100 fibres measured. The lengths of all fibre elements both whole and broken were determined by measuring a projected image with an electro-mechanical probe and a recorder which counted the total number of fibres measured, the sum of the lengths of the fibres and the number of fibres falling in each of 18 length groups, each group representing a 0.5 mm range of fibre length. In this way the average length of fibres in pulp and a distribution curve of lengths were obtained. The widths of the partially collapsed fibres and the wall thickness were determined by direct measurement of the projected image. Because pulping and the pressing during sheet making causes the fibres to collapse the widths are typical of the pulp only. Fibre wall thickness as measured may also differ from that observed on a cross section of wood.

(5) *Pulping Methods*

The chips used for pulping were prepared by sawing the log into discs approximately ¾ inch thick and then splitting along the grain with a mechanical guillotine to give a chip approximately ¾ inch x ¼ inch thick. This damages the fibres less than commercial chipping.

Laboratory pulping was carried out in an electrically-heated, stainless steel, rotating pressure vessel.

The method used was the sulphate (Kraft) process, which was selected as being the most promising process for use on tropical woods in tropical conditions. The active chemicals are sodium hydroxide and sodium sulphide.

The concentration of chemicals is calculated according to the following definitions:

(a) Active Alkali = $NaOH + Na_2S$ expressed as Na_2O per cent on oven-dry wood.

(b) Sulphidity = $\frac{Na_2S \times 100}{NaOH + Na_2S,}$ all the compounds expressed as Na_2O.

A sulphidity of 25 per cent was used in each of these experiments, chosen because published information shows there to be generally little variation in pulp quality with changes in sulphidity in the range of 20 to 30 per cent.

The cooked chips were washed free of superficial black liquor and broken up in a propeller type disintegrator to simulate the disintegration occuring during blowing a commercial digester; the pulp was screened using a plate with 0.15 mm wide slits, to remove shive, and collected on a 150 mesh (per linear inch) sieve.

The yield of pulp was determined by drying the whole of the screened pulp in a stream of air to about 10% moisture. The total weight of air dry screened pulp and the moisture content of an aliquot were determined for calculating the yield of oven-dry pulp.

The total alkali in the black liquor was determined by titrating an ashed aliquot of black liquor with hydrochloric acid. The Active Alkali remaining was determined by titrating an aliquot of black liquor after removing the sodium salts which are the reaction products of digestion by precipitation with barium chloride. The Active Alkali consumed was the difference of these results.

(6) *Unbleached pulp evaluation*

The Kappa Number was determined by TAPPI standard method T 236m-60[1]. This method is identical with the International Committee for Chemical Analyses Method ICCA 1:59 which has been adopted throughout the world.

The amount of permanganate consumed by pulp under specified conditions is measured and, for pulp yields of less than 70 per cent, the percentage of Klason lignin approximately equals Kappa Number XO.15.

The pulp was evaluated by preparing and testing standard sheets, from pulp which had been air dried, according to the proposals of the 'Second Report of the Pulp Evaluation Committee to the Technical

Section of the (British) Papermarkers' Association'[3]. The sheets of approximately 60g/m^2 were tested after conditioning at 20° ± 1°C and 65 per cent relative humidity. The methods given in this report are practically identical with those in TAPPI Standard T205m-58[1]. The effect of air drying is to lower the strength of the unbeaten pulp, but, except for specific scattering coefficient, the effect on beaten pulps is small.

The pulps were beaten in a PFI Mill using a pulp consistency of 10 per cent, a beating pressure of 3.4 kgF (33.3N) per cm of bar length and a difference between the peripheral speeds of the beating elements of 2 m/sec.

The methods used for physical examination of each set of sheets were:

(a) Thickness: Ten measurements made on ten sheets placed one on top of another using a dead weight micrometer.

(b) Breaking length and stretch: Twelve strips 15 mm wide tested using a Schopper-type tensile tester with the jaws initially 9 cm apart.

(c) Tear: Using a Marx-Elmendorf tear tester; normally a group of three were torn at one time through 44 mm in 2 places (i.e. total tearing distance is 3 x 2 x 44 = 264 mm), three readings being obtained in this way. Sheets with high tearing strength were torn either in pairs or singly and suitable adjustment was made to the calculation of the tear factor.

(d) Burst: Eighteen tests using a Frank Schopper-Dalen type pneumatic burst tester.

(e) Fold: 15 mm strips folded through 312° and the number of double folds recorded before the strip broke under a load of 7.85 N(800gF).

(f) Air porosity: Four sheets tested using a closed top Gurley Densometer with a 20 ounce inner cylinder. The time for 100 ml of air to pass through 1 sq. inch was measured by the automatic timing attachment.

(g) Basic weight and moisture content: Determined by weighing six rectangles of 250 cm^2 after standard conditioning and after drying to constant weight at 105° + 3°C.

Results are reported as follows, where possible, independent of basis weight, but otherwise referring to an oven dry basis weight of approximately 60g/m^2.

Basic weight: Grams per square metre, oven dry (W)

Thickness: Thickness of a single sheet, in microns.

Bulk* $\dfrac{\text{Thickness}}{W}$

Burst Factor* $\dfrac{\text{Average burst in g/cm}^2}{W}$

Tear Factor* $\dfrac{\text{Tearing force for a single sheet in g} \times 100}{W}$

Breaking Length* $\dfrac{\text{Average tensile strength in kg} \times 66{,}700}{W}$

The result is expressed in metres.

* results which are independent of basis weight.

The ease with which water parts from the pulp was determined by two methods. The first, the drainage time determined on the standard sheet machine, is the time in seconds for water at 20°C to flow from a pulp suspension through the wire from a height 350 mm above the wire until the formed sheet is no longer immersed. The procedure used was that described in the 'Second Report of the Pulp Evaluation Committee'[3] and is similar to that given in TAPPI Standard T221os-63[1].

The second, the Canadian Standard freeness is an empirical measure of the rate at which water will separate from a one litre suspension of 3 grams of pulp through a standard perforated plate, in apparatus calibrated by the Pulp and Paper Research Institute of Canada. The method is described in the 'Second Report of the Pulp Evaluation Committee[3], TAPPI Standard T227m-58[1] and in Canadian Pulp and Paper Association Standard C1.

Bleaching trials were carried out by a four stage method of chlorination extraction, hypochlorite and chlorine dioxide (CEHD). This is the simplest sequence currently used to obtain a fully bleached sulphate pulp. The quantity of chlorine added, sufficient to give an excess that would not be consumed within the reaction time, was estimated from the Kappa number using data for the relationship between Kappa number and chlorine demand from earlier trials.

The brightness was determined using an Elrepho reflection photometer using a "Tappi" filter (with an effective wavelength of 457 nm) and a Magnesium oxide standard as 100.

The printing opacity was determined using the same instrument with CIE tristimulus filters Y (green). The reflectance from a single 60 g/m^2 sheet (Ro) over a black background was compared with the relectance from a pad sufficiently thick to ensure no light was transmitted (R∞).

Then printing opacity = $\frac{Ro \times 100}{R\infty}$ This figure is dependent on the basic weight of the sheet.

The scattering power (SX) was determined from the relationship between the printing opacity $\frac{(Ro \times 100)}{(R\infty)}$ and the total reflectance. The specific scattering coefficient(s), which is independent of the basis weight is given by:

$$s = \frac{SX \times 10{,}000}{W}$$

where W = Basis Weight, oven dry in g/m^2. (4)

The strength characteristics of the bleached pulps were determined as described for unbleached pulps.

REFERENCES

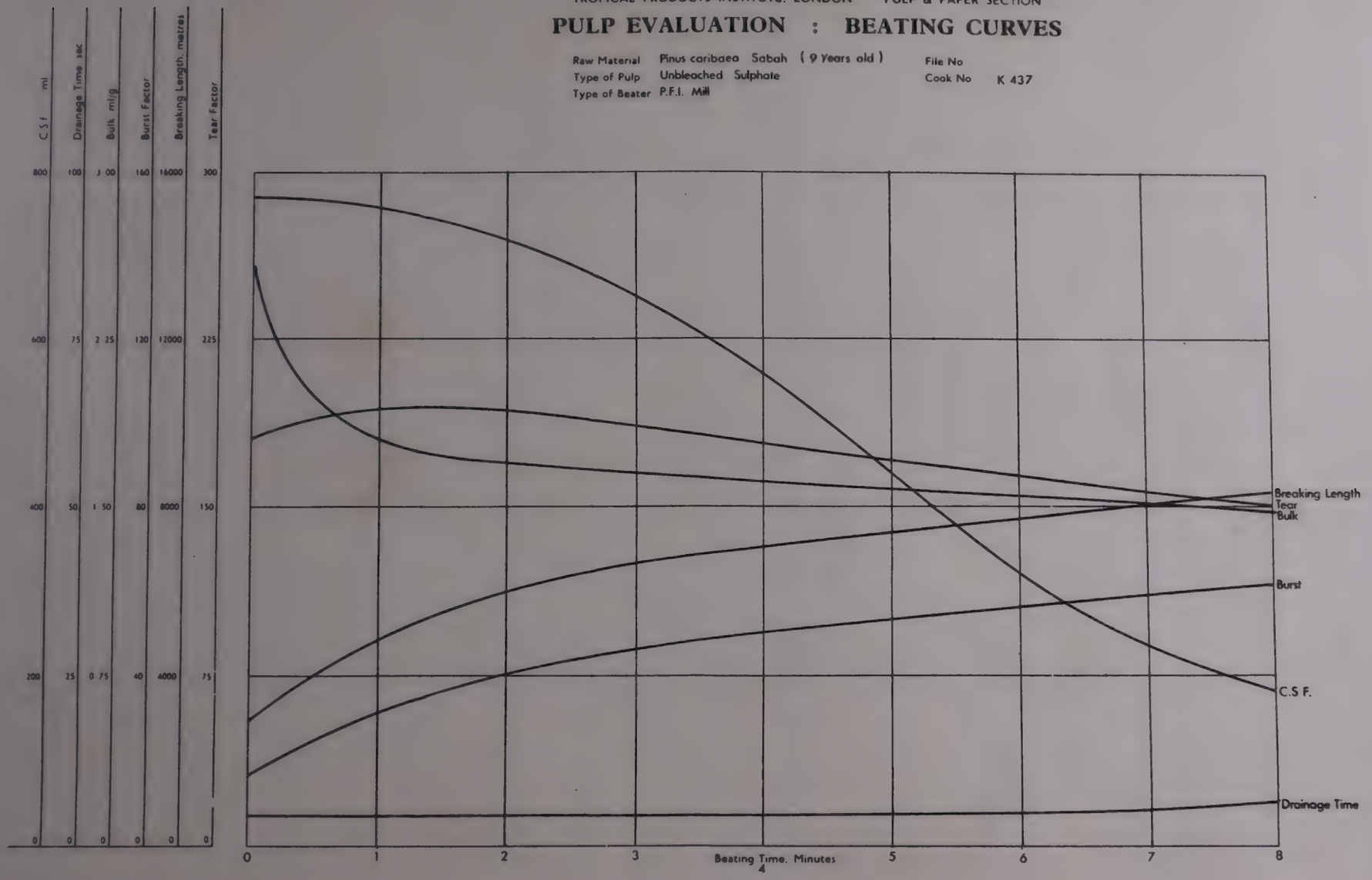
1. TAPPI Standard and Suggested Methods, Published by the Technical Association of the Pulp and Paper Industry, New York.
2. L. E. WISE, M. MURPHY and A. A. D'ADDIECO, *Paper Trade J.* 1946, **122**, No. 2,35.
3. Second Report of the Pulp Evaluation Committee to the (British) Paper Makers' Association, London, 1936.
4. H. W. GIERTZ, *Svensk Papperstidning*, 1950, **53**, 673.

TROPICAL PRODUCTS INSTITUTE, LONDON PULP & PAPER SECTION

PULP EVALUATION : BEATING CURVES

Raw Material Pinus caribaea Sabah (9 Years old)
Type of Pulp Unbleached Sulphate
Type of Beater P.F.I. Mill

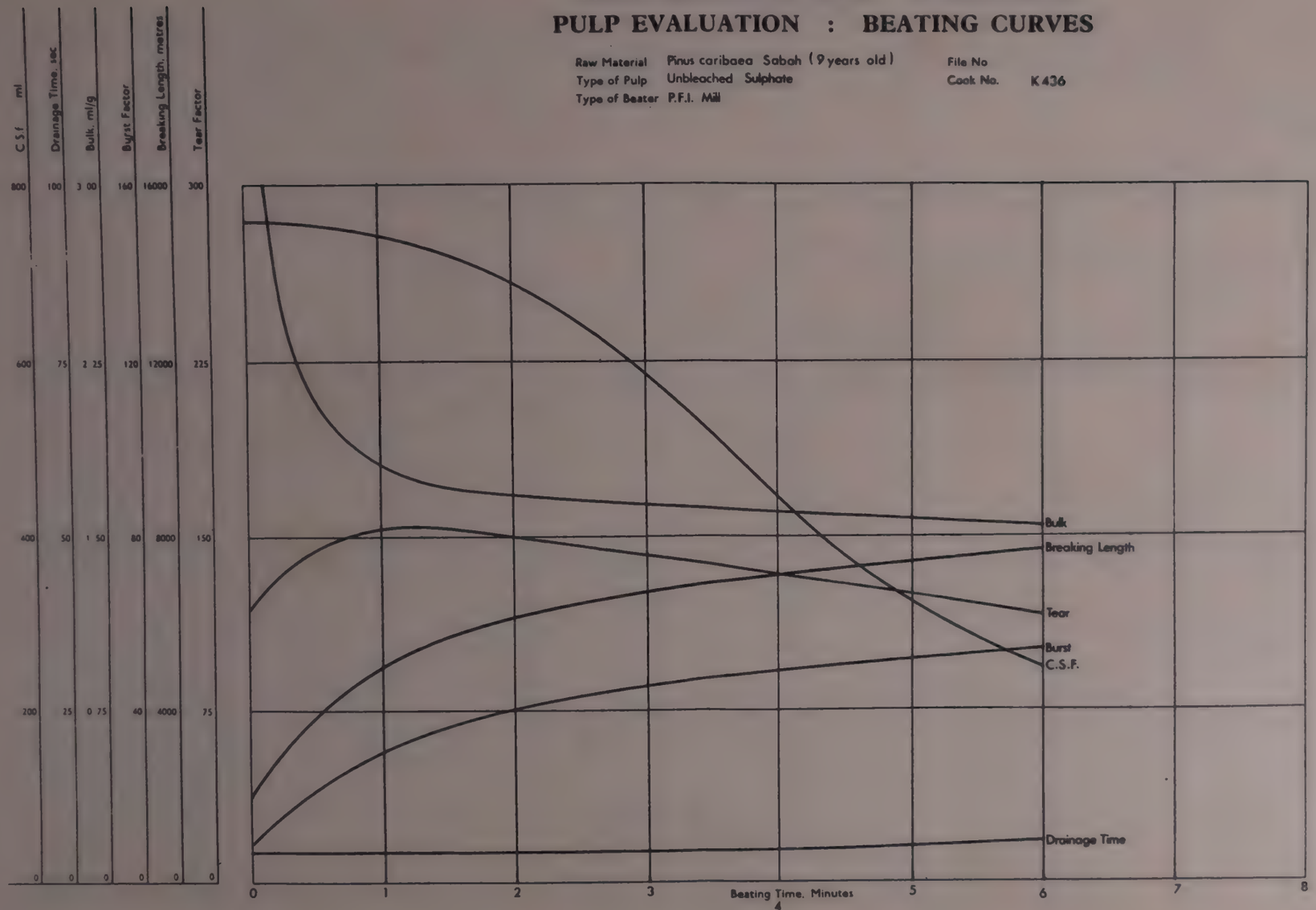
File No
Cook No K 437



TROPICAL PRODUCTS INSTITUTE, LONDON . PULP & PAPER SECTION

PULP EVALUATION : BEATING CURVES

Raw Material Pinus caribaea Sabah (9 years old) File No
Type of Pulp Unbleached Sulphate Cook No. K436
Type of Beater P.F.I. Mill

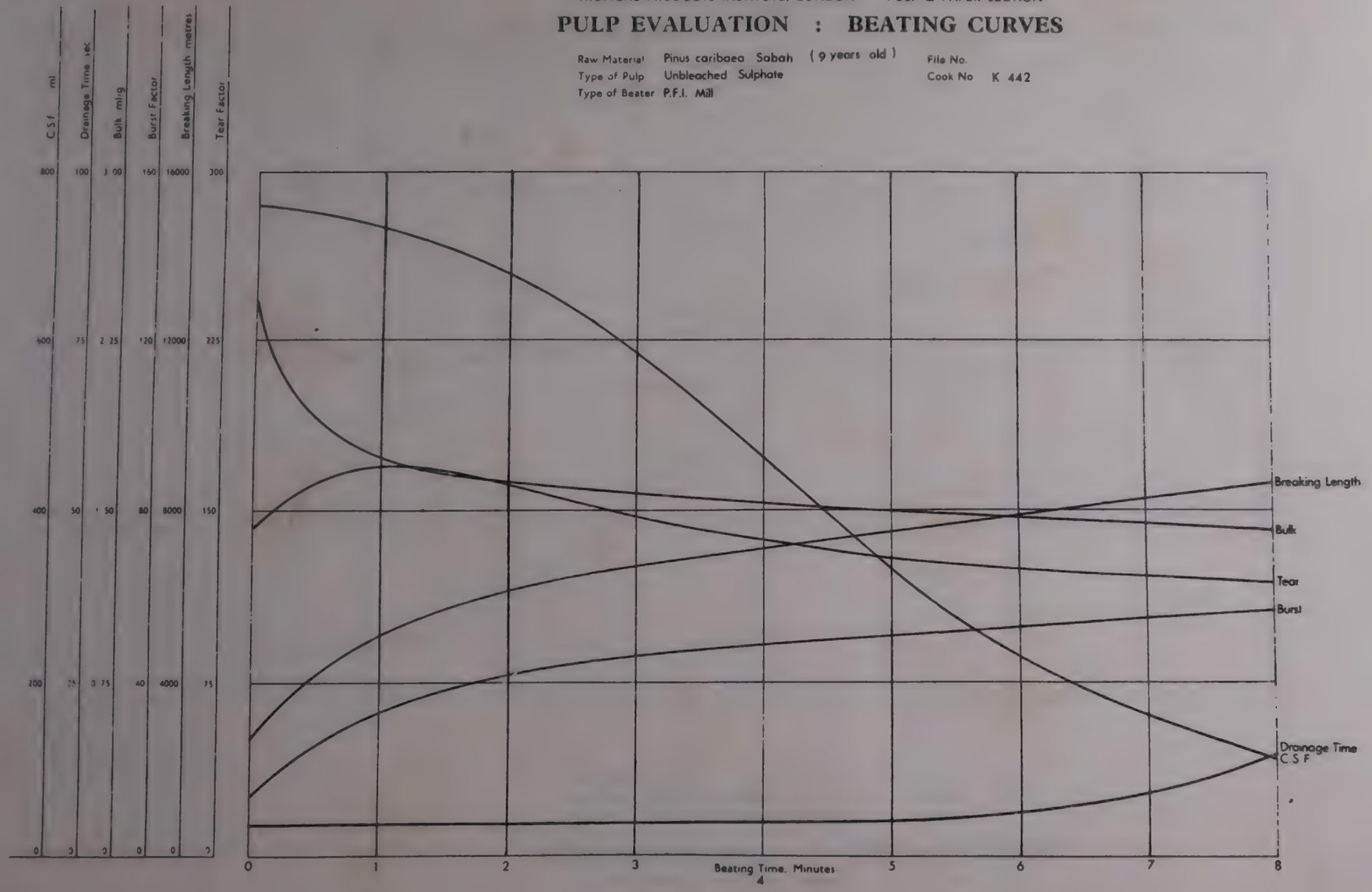


TROPICAL PRODUCTS INSTITUTE, LONDON PULP & PAPER SECTION

PULP EVALUATION : BEATING CURVES

Raw Material Pinus caribaea Sabah (9 years old)
Type of Pulp Unbleached Sulphate
Type of Beater P.F.I. Mill

File No.
Cook No K 442

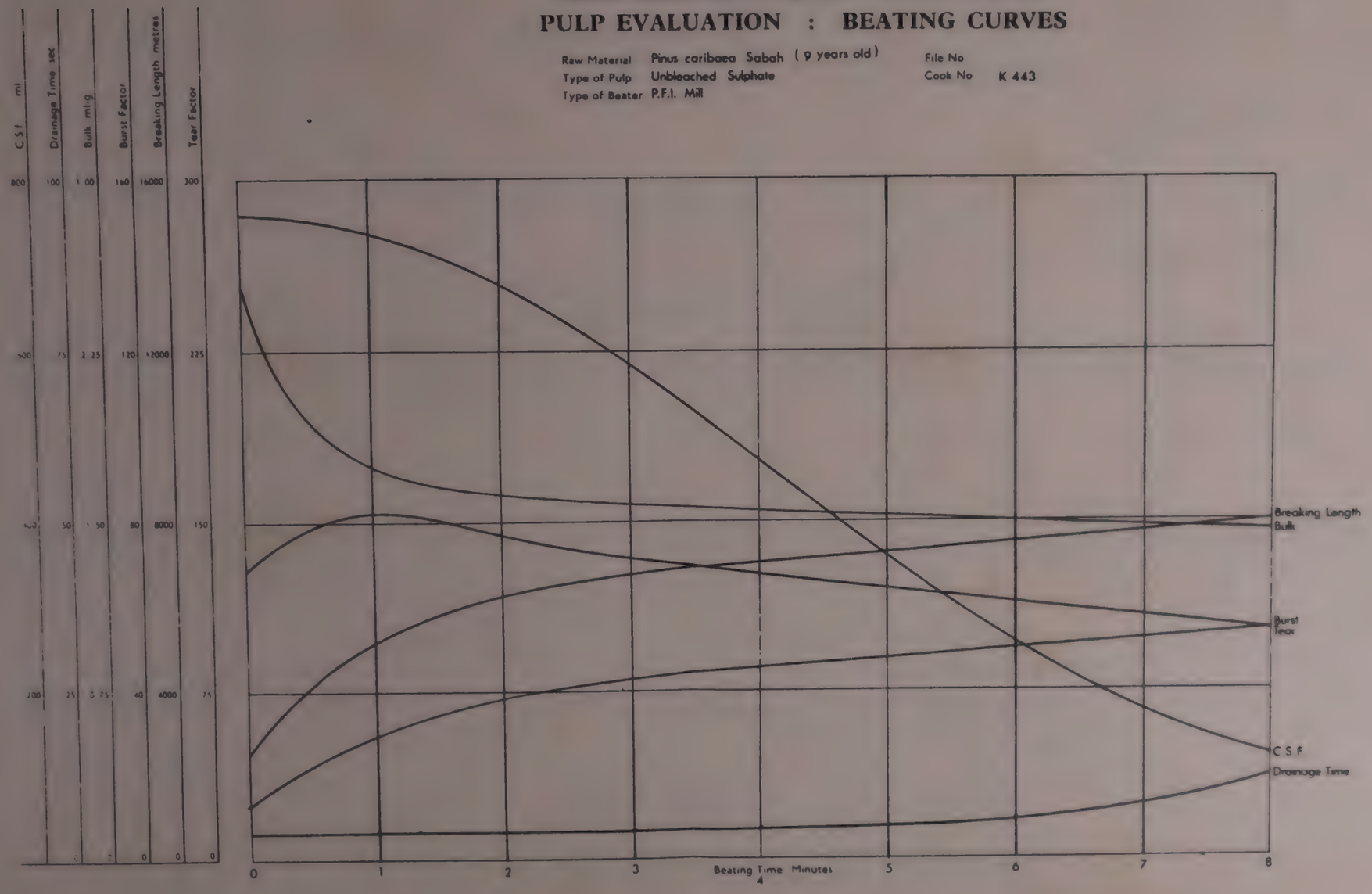


TROPICAL PRODUCTS INSTITUTE, LONDON . PULP & PAPER SECTION

PULP EVALUATION : BEATING CURVES

Raw Material Pinus caribaea Sabah (9 years old)
Type of Pulp Unbleached Sulphate
Type of Beater P.F.I. Mill

File No
Cook No K 443

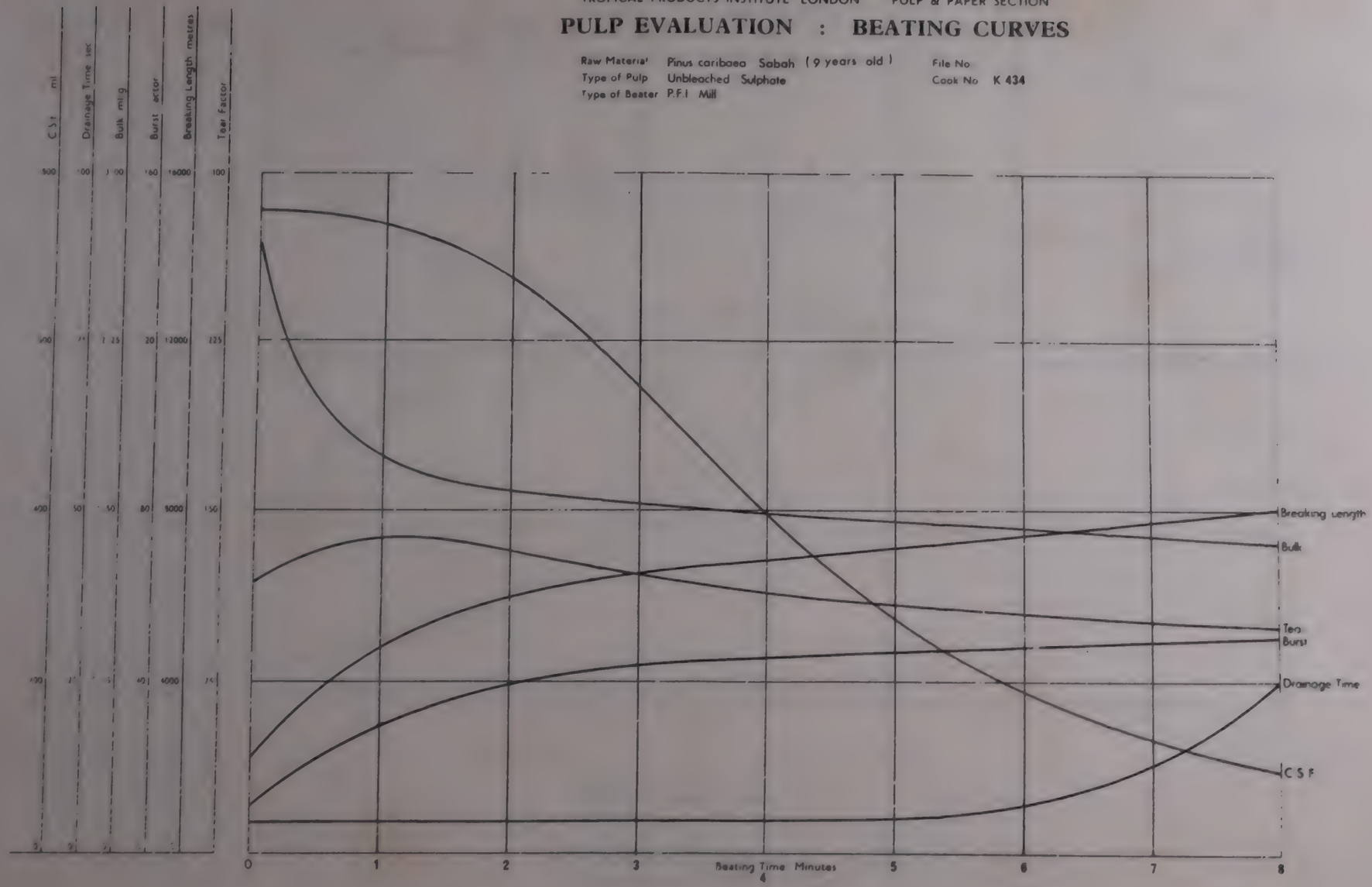


TROPICAL PRODUCTS INSTITUTE LONDON PULP & PAPER SECTION

PULP EVALUATION : BEATING CURVES

Raw Material Pinus caribaea Sabah (9 years old)
Type of Pulp Unbleached Sulphate
Type of Beater P.F.I Mill

File No
Cook No K 434



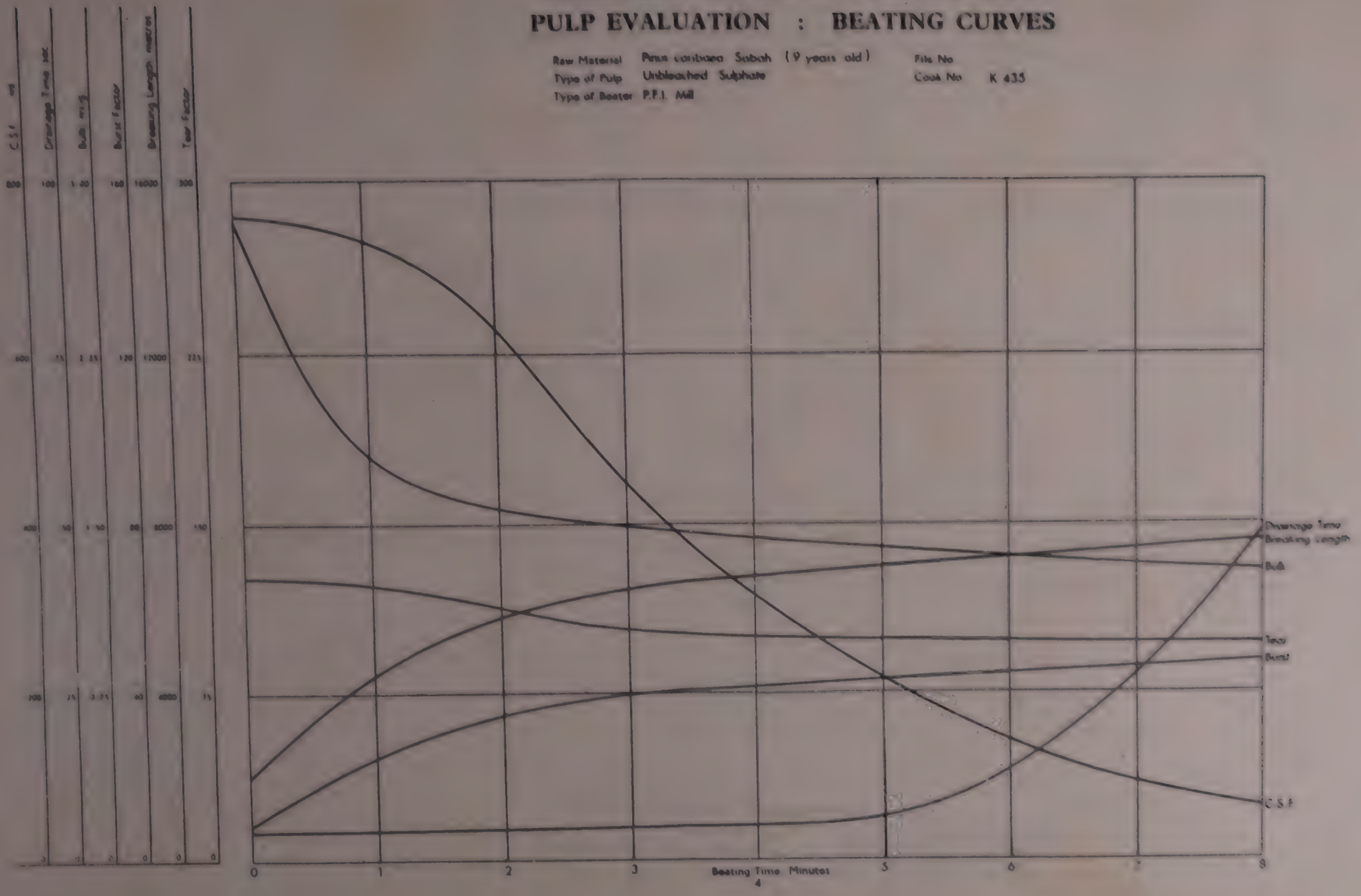
TROPICAL PRODUCTS INSTITUTE, LONDON PULP & PAPER SECTION

PULP EVALUATION : BEATING CURVES

Raw Material *Pinus caribaea* Sabah (9 years old) File No

Type of Pulp Unbleached Sulphate Cook No K 435

Type of Beater P.F.I. Mill

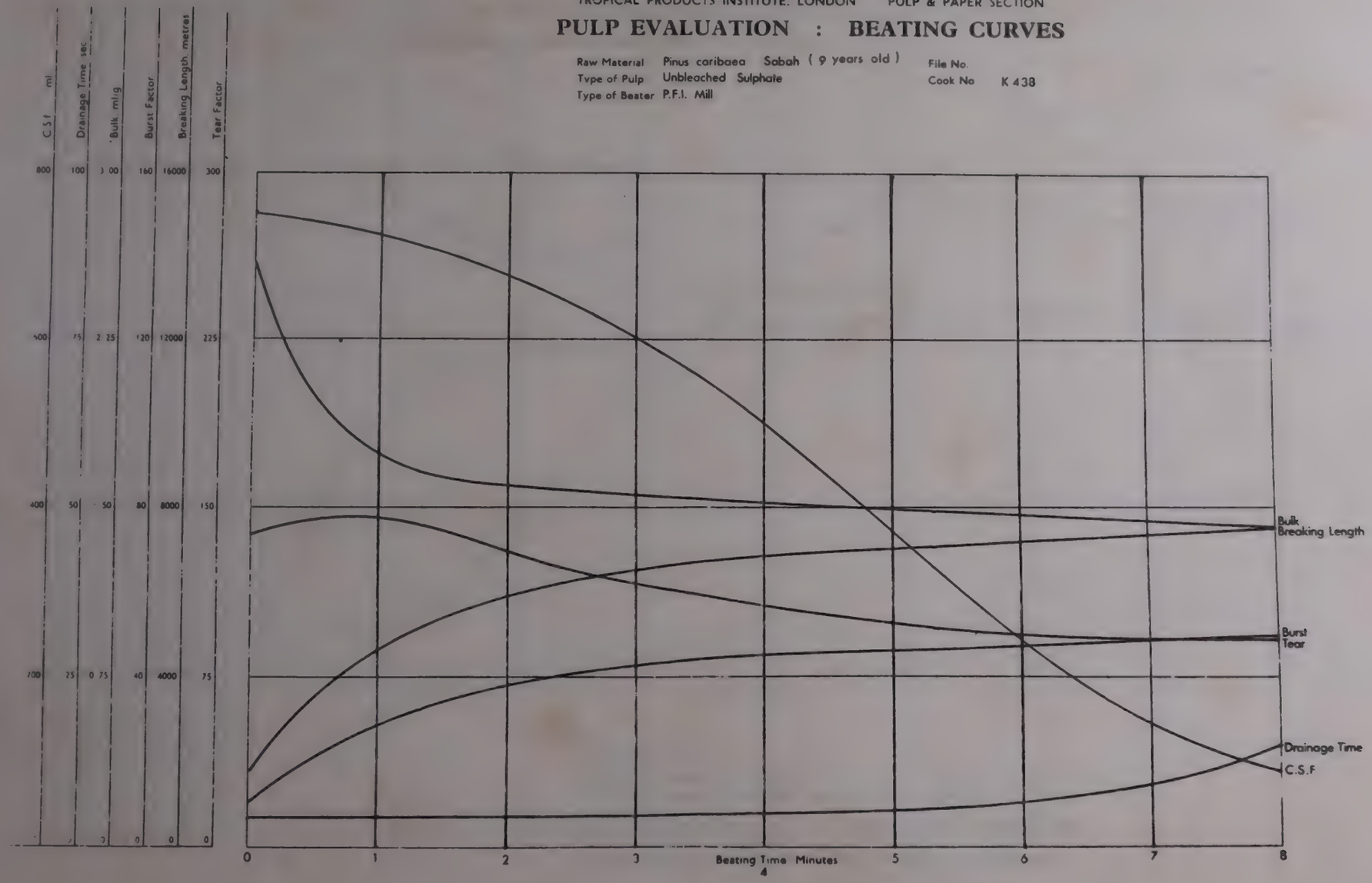


TROPICAL PRODUCTS INSTITUTE. LONDON PULP & PAPER SECTION

PULP EVALUATION : BEATING CURVES

Raw Material Pinus caribaea Sabah (9 years old)
Type of Pulp Unbleached Sulphate
Type of Beater P.F.I. Mill

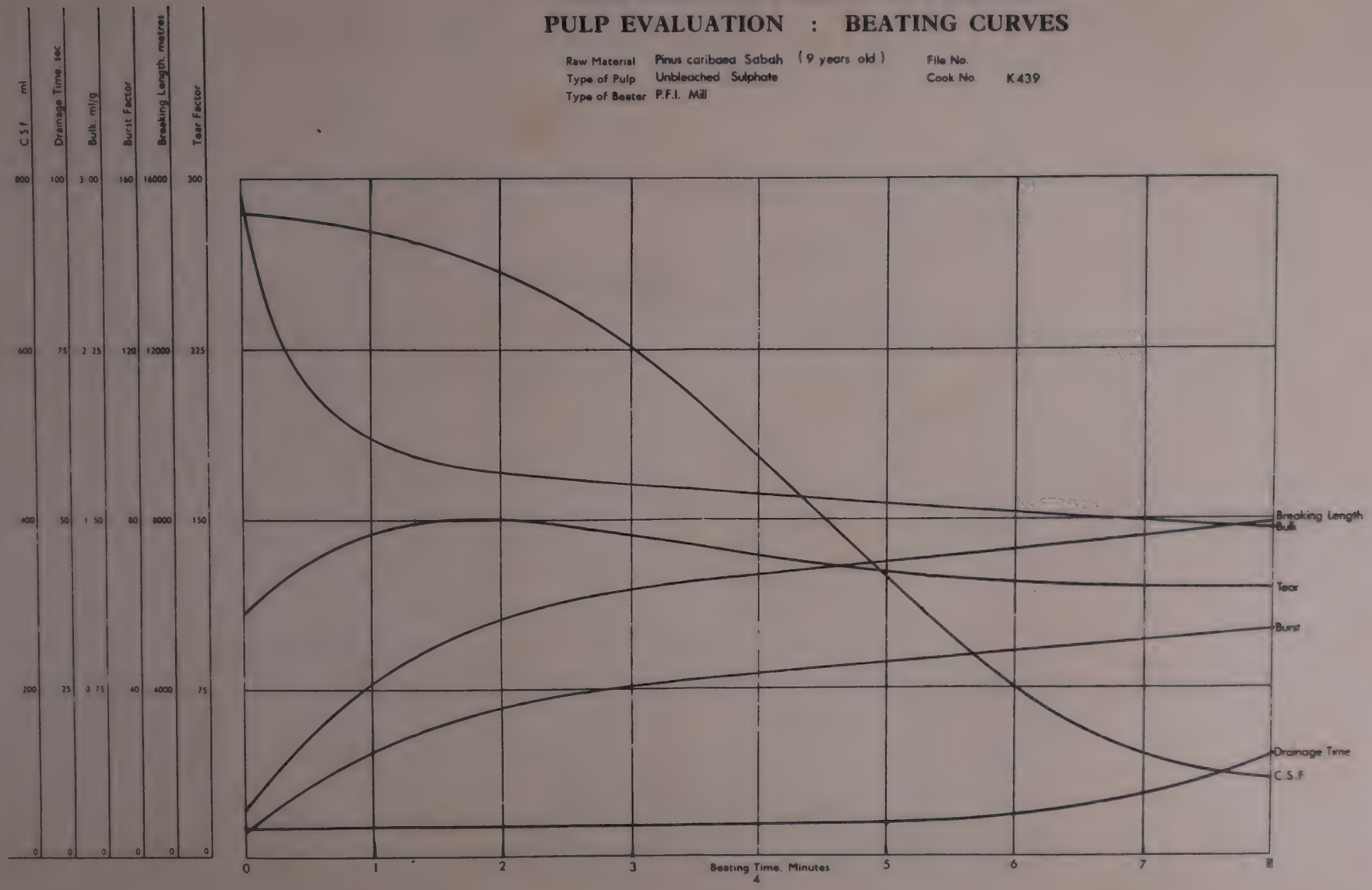
File No.
Cook No K 438



TROPICAL PRODUCTS INSTITUTE. LONDON PULP & PAPER SECTION

PULP EVALUATION : BEATING CURVES

Raw Material Pinus caribaea Sabah (9 years old) File No.
Type of Pulp Unbleached Sulphate Cook No. K439
Type of Beater P.F.I. Mill

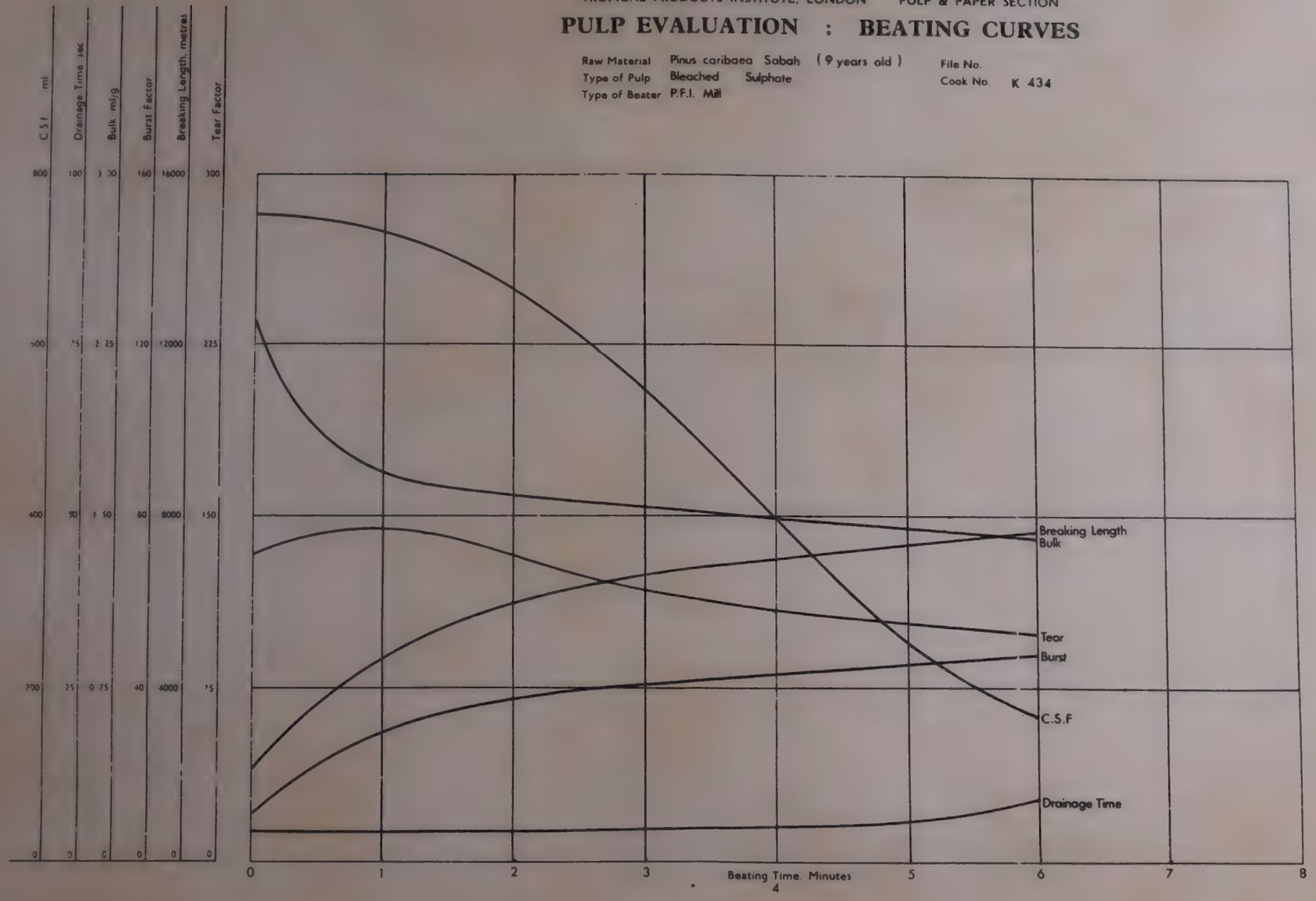


TROPICAL PRODUCTS INSTITUTE, LONDON PULP & PAPER SECTION

PULP EVALUATION : BEATING CURVES

Raw Material Pinus caribaea Sabah (9 years old)
Type of Pulp Bleached Sulphate
Type of Beater P.F.I. Mill

File No.
Cook No. K 434

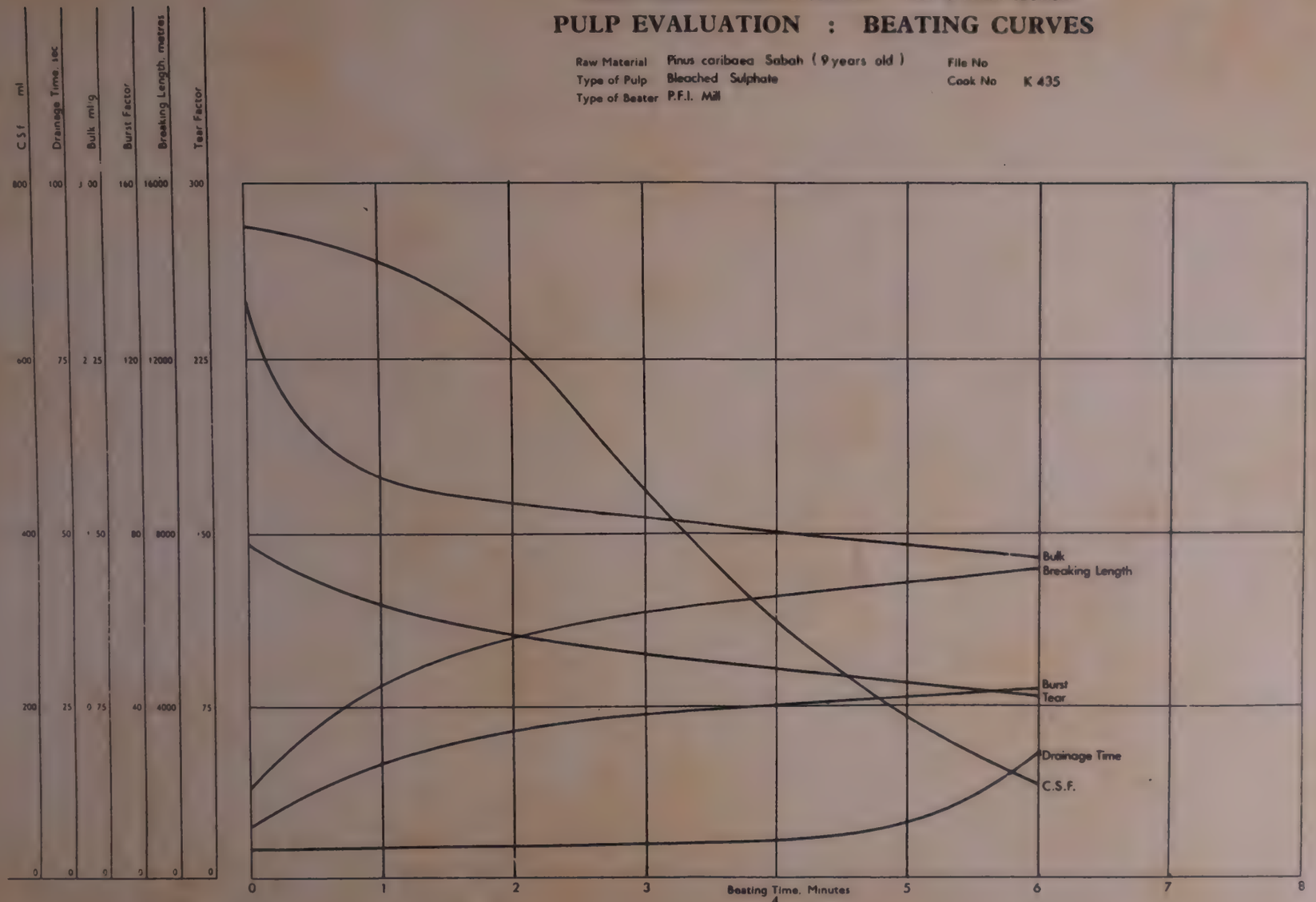


TROPICAL PRODUCTS INSTITUTE. LONDON PULP & PAPER SECTION

PULP EVALUATION : BEATING CURVES

Raw Material Pinus caribaea Sabah (9 years old)
Type of Pulp Bleached Sulphate
Type of Beater P.F.I. Mill

File No
Cook No K 435



LIBRARY AND DOCUMENTATION UNIT
Acc. No
Call. No
C.F.T.R.I., MYSORE

Tropical Products Institute

28

An exploratory study of the suitability of *Pinus caribaea* for the production of dissolving pulps

Tropical Products Institute

28

An exploratory study of the suitability of *Pinus caribaea* for the production of dissolving pulps

Wong Wing Chong and E. R. Palmer

March 1973

Tropical Products Institute 56/62 Gray's Inn Road London WC1X 8LU

Foreign and Commonwealth Office (Overseas Development Administration)

This report was produced by the Tropical Products Institute, a British Government organization which helps developing countries to derive greater benefit from their renewable resources.

It specializes in post-harvest problems and will be pleased to answer requests for information and advice.

Reproduction of this report, in whole or in part, is gladly permitted provided that full acknowledgement is given to the Tropical Products Institute, Foreign and Commonwealth Office (Overseas Development Administration), and to the authors.

Requests for further information should be addressed to:

The Director
Tropical Products Institute
56/62 Gray's Inn Road
London WC1X 8LU

Tropical Products Institute
ISBN: 0 85954 005 7

Contents

	Page
SUMMARIES	
Summary	1
Sommaire	2
Resumen	2
OBJECTS OF INVESTIGATION	5
SAMPLES	5
EXPERIMENTAL METHODS	
Physical examinations	5
Chemical examination	6
Pulping and bleaching	6
RESULTS AND DISCUSSION	
Physical examinations: bark/wood ratio	6
apparent density	6
Chemical examination	7
Pulping and bleaching of original wood without prehydrolysis	7
Prehydrolysis conditions	9
Kraft digestion and bleaching of prehydrolysed chips	9
COMPARISON WITH COMMERCIAL PULPS	12
CONCLUSIONS	12
REFERENCES	15
TABLES	
1 *Pinus caribaea* from Sabah, 9 year old sample Bark content and wood density	7
2 *Pinus caribaea* from Sabah, 9 year old sample Kraft pulping, bleaching and pulp analysis	8

Page

TABLES (*continued*)

3 *Pinus caribaea* from Sabah, 9 year old sample
Prehydrolysis conditions and analysis of prehydrolysed chips 10

4 *Pinus caribaea* from Sabah, 9 year old sample
Prehydrolysis, Kraft pulping, bleaching, pulp analysis 11

5 Comparison of *Pinus caribaea* bleached pulps and commercial grades 12

Summaries

SUMMARY

The results of an exploratory study of the suitability of *Pinus caribaea* for the production of dissolving pulps are reported.

The findings are not conclusive because:

a. no attempt was made to evaluate pulps beyond their chemical composition and viscosity;

b. the time available was insufficient for determining the optimum processing conditions.

The wood was grown in Sabah and was cut at 9.5 years old. The results of its examination for papermaking pulp were the subject of Tropical Products Institute Report L25 (1971).

Ordinary kraft pulps, made without prehydrolysis, were used to compare bleaching in a five stage sequence including sodium hypochlorite (CEHEH), with a similar sequence using chlorine dioxide in place of hypochlorite (CEDED).

Bleached pulp yields were around 39%. Alpha-cellulose contents were mostly around 88%, cuprammonium viscosities between 9 and 17 cp and brightnesses never more than 78, which indicated that these pulps were not suitable for dissolving pulps.

Bleaching using hypochlorite caused greater reduction in viscosity than when using chlorine dioxide and it was decided to use CEDED bleaching in all the prehydrolysis-kraft pulps made subsequently.

Prehydrolysis of the raw chips at 120°C removed little or no hemi-cellulose, but at higher temperatures of 145° and 170°C hemi-celluloses were removed preferentially; however if the hydrolysis time was unduly prolonged alpha-cellulose was removed as well.

Kraft cooking of the prehydrolysed chips, using 17.5 to 21.5% active alkali as Na_2O on the original wood, could be effected in a shorter time but without much reduction in the alkali dose compared with cooking raw chips. After cooking the yields were about 34.5% on original wood, the cuprammonium viscosities between 19 and 13 cp, Kappa numbers between 30 and 22 and alpha-cellulose contents about 85. After CEDED bleaching, yields of about 33%, alpha-cellulose contents of about 96%, brightnesses of 82 to 85, and cuprammonium viscosities of 10.1 to 12.4 cp were obtained. Compared with published evaluations of a number of dissolving pulps, these pulps had satisfactory alpha-cellulose contents, low but, for some purposes, adequate viscosities and low brightnesses.

SOMMAIRE

On donne les résultats d'une étude exploratrice sur la convenance du *Pinus caribaea* pour la fabrication de pâtes à usage chimique. Les découvertes ne sont pas conclusives parce que:

a. on ne chercha pas à évaluer les pâtes au delâ de leur composition chimique et de leur viscosité;

b. la durée allouée pour la détermination des conditions optimum était insuffisante.

Les arbres ayant poussé à Sabah furent coupés à l'âge de 9,5 ans. Les résultats de l'examen du bois comme essence papetière firent l'objet du rapport TPI L25 (1971).

On utilise les pâtes kraft ordinaires confectionnées sans préhydrolyse pour comparer la séquence de blanchissage en cinq étapes comprenant l'hypochlorite (H) de sodium (CEHEH) avec une séquence similaire (CEDED) utilisant du bioxide de chlore (D) au lieu d'hypochlorite.

Les rendements en pâte blanchie étaient d'environ 39%. Les teneurs en alpha-cellulose étaient pour la plupart d'environ 88% les viscosités des solutions cupro-ammoniacales de 9 à 17 cp, et la blancheur, jamais plus de 78, indiquant que ces pâtes ne conviennent pas à la fabrication de pâtes à usage chimique.

Le blanchiment à l'hypochlorite entraîna des abaissements de la viscosité plus importants que le blanchiment au bioxide de chlore. On décida d'utiliser le blanchiment au CEDED pour toutes les pâtes kraft préhydrolysées préparées par la suite.

La préhydrolyse à 120° C des copeaux bruts n'enleva pour ainsi dire pas d'hémi-cellulose, mais aux températures plus élevées 145° et 170°C, les hémi-celluloses furent enlevées préférentiellement; cependant, les hydrolyses dont la durée fut excessivement prolongée, enlevèrent aussi l'alpha-cellulose.

La cuisson kraft des copeaux préhydrolysés, utilisant des doses d'alcali de 17,5 a 21,5% en tant que Na_2O, sur le bois d'origine, pouvait être effectuée plus rapidement mais sans réduction de la dose d'alcali, en comparaison avec la cuisson des copeaux bruts. Les rendements après la cuisson étaient d'environ 34,5% du bois d'origine, les viscosités des solutions cupro-ammoniacales entre 19 et 13 cp, les indices Kappa entre 30 et 22 et les teneurs en alpha-cellulose environ 85%. Après blanchiment CEDED, on obtint des rendements d'environ 33%, des teneurs en alpha-cellulose d'environ 96%, des degrés de blanchiment de 82 à 85 et des viscosités de solutions cupro-ammoniacales de 10,1 à 12,4 cp. Comparées aux évaluations publiées pour une quantité de pâtes â usage chimique, ces pâtes avaient des teneurs en alpha-cellulose satisfaisantes, des viscosités basses mais dans certains cas suffisantes et des degrés de blanchiment bas.

RESUMEN

Reporte de los resultados de un estudio exploratorio sobre la adaptabilidad del *Pinus caribaea* para la producción de pastas para empleos químicos. Los hallazgos no son concluyentes debido a:

a. No se intentó evaluar las pastas más allá de su composición química y viscosidad;

b. El tiempo disponible era insuficiente para determinar las condiciones óptimas de su elaboración.

La madera fue cultivada en Sabah y cortada a los 9,5 años de edad. Los resultados de su inspección con vistas para hacer papel de la pasta fueron objeto del reporte L25, TPI (1971).

Se usaron pastas kraft ordinarias, hechas sin un prehidrólisis, para comparar blanqueamiento en una secuencia de cinco etapas incluyendo hipoclorito de sodio (Cl, NaOH, OCl, NaOH, OCl), con una secuencia parecida usando bióxido de cloro en lugar de hipoclorito (Cl, NaOH, ClO_2, NaOH, ClO_2).

Los rendimientos de pastas blanqueadas fueron de alrededor de 39%. Sus contenidos de Alpha-cellulosa fueron en su mayoría cerca de un 88%, las viscosidades cuprammonium entre 9 y 17 cp y las blancuras nunca mayor de 78, lo cual nos indicó la inconveniencia de estas pastas para empleos químicos.

El blanqueamiento usando hipoclorito ocasionó una disminución en la viscosidad mayor que cuando se usa bióxido de cloro y se optó por usar la secuencia Cl, NaOH, ClO_2, NaOH, ClO_2 para blanquear todas, las pastas prehidrólisis-kraft hechas subsecuentemente.

Prehidrólisis de las astillas crudas a 120°C eliminó poca o ninguna hemi-celulosa, pero a las temperaturas mas altas de 145° y 170°C las hemi-celulosas fueron preferencialmente eliminada; sin embargo de ser indebidamente prolongado el tiempo de hidrólisis la alpha-celulosa fue atacada también.

El cocimiento kraft de las astillas prehidrolisadas, usando de 17,5 a 21,5% de alcali activo como Na_2O sobre la madera original, podría efectuarse en un período más corto pero sin mucha reducción en la dosis de álcali en comparación con el cocimiento de astillas crudas. Después del cocimiento el rendimiento fue de 34,5% sobre la madera original, las viscosidades cuprammonium entre 19 y 13 cp, los números Kappa entre 30 y 22 y los contenidos de alpha-celulosa alrededor de 85%. Después de la blanqueamiento Cl, NaOH, ClO_2, NaOH, ClO_2, los rendimientos alrededor de 33%, los contenidos de alpha-celulosa alrededor de 96%, blancuras de 82 a 85, y viscosidades cuprammonium de IO,1 a 12,4 cp se obtuvieron. En comparación con evaluaciones publicadas de un número de pastas para empleos químicos estas pastas tuvieron contenidos satisfactorios de alpha-celulosa, viscosidades bajas (pero para algunos usos adecuadas) y bajas blancuras.

An exploratory study of the suitability of *Pinus caribaea* for the production of dissolving pulps

OBJECTS OF INVESTIGATION

The work reported here was undertaken while one of the authors (W.W.C.) was working at the Tropical Products Institute on a Colombo Plan Fellowship in order to gain experience in some laboratory techniques used in investigating the value of fibrous materials for pulp production.

Using a sample of *Pinus caribaea* grown in Sabah, bleached kraft pulps were prepared and analysed to determine some of the more important characteristics that could indicate their value as dissolving pulps.

After finding that these pulps were not suitable for dissolving pulps, conditions for prehydrolysis of chips were determined; bleached kraft pulps were prepared from the prehydrolysed chips and these pulps similarly evaluated.

The sample used had previously been examined as a raw material for a papermaking pulp.[1]

SAMPLES

The sample pulped was *Pinus caribaea* var *hondurensis* planted in Sabah in October 1959 using seed from British Honduras.

Six trees, selected to be statistically representative of the site, were felled in April 1969; their age at this time was 9 years 6 months. Details of the girths of these six trees are given in Table 1. Their mean girth under bark at breast height was 2.02 feet (616 mm) which was below the average for the site of 2.19 feet (688 mm). Three logs each 2.5 feet (0.76 m) long, were cut from each tree with mid point heights of 4.5 feet (1.4 m), 9.5 feet (2.9 m) and 14.5 feet (4.4 m).

The density was determined on each log, but for all other determinations a composite sample of all logs was prepared.

EXPERIMENTAL METHODS

Physical examinations

a. **Bark:** The proportion of bark by volume on the breast height log from each tree was calculated from the over and under bark girth dimensions. The proportion by weight was determined on all the logs by stripping the bark, drying it at 105°C and calculating the weight of wood from its volume and density. In each case the proportion of bark is expressed as a fraction of the whole log (i.e. wood plus bark).

b. **Density:** One $\frac{5}{8}$ inch (16 mm) thick disc was cut from each log, sanded and its density determined in accordance with TAPPI standards (T18)[2].

Chemical examination

A suitable quantity of chips from the bulk sample was ground and the ground wood that passed through a BS-40 mesh screen (420 microns) and was retained on a BS-60 mesh screen (150 microns) was used for analysis. Using Tappi standard methods[2] alcohol-benzene solubility (T6), alpha-cellulose (T203), 1% caustic soda solubility (T4) were determined; holocellulose was determined following the method of Wise *et al*[3].

Pulping and bleaching

Prehydrolysis and kraft digestions were made using 50 g samples of wood chips in indirectly heated rotating digestion vessels.

To assess the effectiveness of varying prehydrolysis conditions, the prehydrolysed chips were washed thoroughly, dried and ground, before determining the holocellulose, alpha-cellulose and lignin by the methods given above.

The digested pulps were washed, disintegrated, and screened using 0.15 mm width slots. The yield of pulp, Kappa number (T236), holocellulose, alpha-cellulose and cuprammonium viscosity (T206) were determined on the unbleached pulps.

Pulps were bleached using a five stage sequence of chlorination, alkaline extraction, sodium hypochlorite, alkaline extraction and sodium hypochlorite (CEHEH) or chlorination, alkaline extraction, chlorine dioxide, alkaline extraction, chlorine dioxide (CEDED). Cuprammonium viscosity and alpha-cellulose were determined by the TAPPI standard methods. Brightness was determined on sheets formed on the British Standard sheet machine using an Elrepho brightness meter with 457 mm filter.

Alpha cellulose contents were determined directly on the bleached pulps, but in the case of prehydrolysed chips and unbleached pulps, on the holocellulose obtained from them.

RESULTS AND DISCUSSION

Physical examinations

a. *Bark wood ratio*

The results of the determination of the proportion of bark by volume and by weight are given in Table 1.

The mean values were 25 per cent of bark by volume, 12 per cent by weight. These values were a little lower than those found when younger wood was examined, but are higher than those normally found in temperate pulpwoods, for which Casey gives typical values as 15 per cent by volume and 7 to 8 per cent by weight.[4]

b. *Apparent density*

Values for the apparent density of the wood, expressed as oven dry weight/green (soaked) volume, are given in Table 1. In most cases the variation of density within the tree was not very large. The mean value for all trees was 445 kg/m^3 (27.8 lbs/ft^3) and the means for individual trees ranged between 385 kg/m^3 and 550 kg/m^3. There was not a direct relationship between density and rate of growth as indicated by girth; the most dense sample was the slowest grown, but the least dense was not the fastest grown.

The density was in the range of densities of pines used in the pulp industry.

Table 1

***Pinus caribaea* from Sabah, 9 year old sample**

Bark content and wood density

Tree/log number	Height of midpoint of log, feet	Girth, cm		Bark/wood plus bark		Density of wood	
		Overbark*	Underbark	by volume* %	by dry weight %	Dry wt/green vol kg/m^3	lb/ft^3
1/1	4.5	61.0	53.3	24	14	450	28.1
1/2	9.5		50.8		12	385	24.1
1/3	14.5		46.4		10	420	26.3
Average for Tree 1					12	425	26.5
2/1	4.5	61.0	49.5	34	17	510	31.8
2/2	9.5		49.5		17	440	27.4
2/3	14.5		45.7		16	440	27.4
Average for Tree 2					17	465	29.0
3/1	4.5	71.8	63.5	22	13	510	31.8
3/2	9.5		44.4		14	365	22.8
3/3	14.5		40.6		12	505	31.4
Average for Tree 3					13	475	29.6
4/1	4.5	64.8	55.9	26	14	380	23.6
4/2	9.5		53.5		10	395	24.7
4/3	14.5		47.0		10	375	23.3
Average for Tree 4					12	385	23.9
5/1	4.5	58.4	50.8	24	10	450	28.0
5/2	9.5		48.3		14	400	24.8
5/3	14.5		44.4		10	425	26.4
Average for Tree 5					11	425	26.5
6/1	4.5	51.4	45.7	21	11	550	34.3
6/2	9.5		40.6		10	560	34.9
6/3	14.5		36.8		10	535	33.5
Average for Tree 6					11	550	34.3
Grand average for site		61.6*	53.1*	25*	12	445	27.8

*at breast height (4.5 feet)

Chemical examination

The following results were obtained in the chemical analysis of the original wood:

Alcohol-benezene solubility, per cent	0.9
Hot water solubility, per cent	2.9
Holocellulose, per cent	61.7
Alpha-cellulose, per cent	40.9
Lignin, per cent	30.2

All the above values are expressed as a percentage of the oven dry (od) weight of wood. They are fairly typical of softwoods, except perhaps for the low resin content, as indicated by the alcohol-benzene solubility, and the rather low holocellulose fraction. The latter is reflected in the yields of pulp which were obtained.

Pulping and bleaching of original wood without prehydrolysis

Three kraft cooks were made on original wood chips using conditions which previous experience had suggested would yield bleachable grades of pulp. Details of the pulping conditions, yield and analysis of the pulp are given in Table 2.

The three pulping conditions studied yielded pulps with Kappa numbers between 24 and 28 and screened yields of only just over 40%. There was no significant difference in the holocellulose and alpha-cellulose contents of the three pulps. All the pulps had viscosities just above 20 cp; the viscosity had a direct relationship

Table 2

Pinus caribaea **from Sabah, 9 year old sample**

Kraft pulping, bleaching and pulp analysis

Cook Number	BK71		BK72		BK73	
Active Alkali as Na_2O% on oven dry wood	22.5		21.25		20	
Sulphidity, %	25		25		25	
Ratio of liquor to oven dry wood, litre/kg	6:1		6:1		6:1	
Maximum temperature, °C	170		170		170	
Time to reach maximum temperature, hours	1		1		1	
Time at maximum temperature, hours	4		4		5	
Yield						
Yield, oven dry pulp % oven dry wood	41.3		41.3		40.1	
Screenings, on 0.15 mm slits, % oven dry pulp	0.2		less than 0.1		less than 0.1	
Yield, screened pulp % oven dry wood	41.2		41.3		40.1	
Analysis of Screened, unbleached pulp						
Kappa Number	24.8		26.3		27.8	
Holo-cellulose, % oven dry pulp	96.2		96.1		97.2	
Alpha-cellulose, % oven dry pulp	79.9		80.7		80.0	
Cuprammonium viscosity, cp	21.2		22.7		23.6	
Bleaching						
Sequence	CEHEH	CEDED	CEHEH	CEDED	CEHEH	CEDED
1. *Chlorination* (2% pulp consistency, 1 hour at 20°C)						
Chlorine applied as Cl_2% on oven dry unbleached pulp	5.5	5.5	5.5	5.5	5.5	5.5
Chlorine consumed as Cl_2% on oven dry unbleached pulp	5.1	5.3	5.1	5.3	5.2	5.3
pH	2.1	1.8	2.1	1.8	2.0	1.8
2. *Alkali extraction* (6% pulp consistency, 1 hour at 60°C)						
NaOH % oven dry unleached pulp	3.0	3.0	3.0	3.0	3.0	3.0
pH	11.4	11.7	11.4	11.4	11.5	11.7
3. *Hypochlorite or chlorine dioxide stage* (6% pulp consistency if Sodium hypochlorite used 2 hours at 35°C if Chlorine dioxide used 2 hours at 70°C)						
Available Chlorine applied as Cl_2% oven dry unbleached pulp	1.5	1.6	1.5	1.6	1.5	1.6
Available Chlorine consumed as Cl_2% oven dry unbleached pulp	1.4	1.6	1.4	1.6	1.4	1.6
pH	7.8	2.7	7.6	2.9	7.6	2.8
4. *Alkali extraction* (as stage 2)						
NaOH% oven dry unbleached pulp	1.0	1.0	1.0	1.0	1.0	1.0
pH	11.8	11.6	11.8	11.6	11.8	11.6
5. *Hypochlorite or chlorine dioxide stage* (as stage 3)						
Available Chlorine applied as Cl_2% oven dry unbleached pulp	1.0	1.0	1.0	1.0	1.0	1.0
Available Chlorine consumed as Cl_2% oven dry unbleached pulp	0.3	1.0	0.3	1.0	0.3	1.0
pH	8.8	3.0	8.6	3.2	8.8	3.2
Summary						
Total Chlorine applied as Cl_2% unbleached pulp	8.0	8.1	8.0	8.1	8.0	8.1
Total Chlorine consumed as Cl_2% unbleached pulp	6.7	7.8	6.8	7.9	6.9	8.0
Yield of bleached pulp % oven dry wood	39.1	39.4	39.2	39.3	38.0	38.1
Analysis of bleached pulp						
Alpha-cellulose % oven dry bleached pulp	82.9	88.2	88.4	88.3	87.6	88.0
Cuprammonium viscosity, cp	9.3	14.8	10.4	16.0	11.2	16.9
Brightness, Elrepho 457 nm filter	78.4	73.0	76.7	66.8	75.8	61.2

with Kappa number as would be expected, because the pulps of higher Kappa number had been subjected to less severe chemical treatment during pulping at the same temperature.

Each of the three pulps was bleached using both of two five stage sequences mentioned above. The total available chlorine added was the same in each bleaching. An objective was to compare (a) sodium hypochlorite with chlorine dioxide as bleaching agents and (b) the effect of bleaching in an alkaline or an acid medium on the viscosity of the resultant pulps.

The results are given in Table 2. The brightness of all the pulps was poor, and it is thought that too little chlorine was used, particularly in the CEDED sequence. The pulps bleached by the sequence including sodium hypochlorite (CEHEH) had the higher brightness values. The pulps bleached using chlorine dioxide (CEDED) had the higher viscosities. It was not certain that this would have been the case had they been bleached to the same brightness but it was thought preferable to use CEDED in subsequent tests. The alpha-cellulose content was about the same in each case.

Although the results were not conclusive and there were a few discrepancies, it was thought that kraft digestion and five stage bleaching were alone unlikely to produce a pulp suitable for dissolving grades and it was decided to proceed with prehydrolysis kraft cooking.

Prehydrolysis conditions

The analyses of the prehydrolysed chips after nine different treatments are given in Table 3.

When prehydrolysed at 120°C, there was a loss of weight of only 2 or 3% and the holocellulose, alpha-cellulose and lignin of the treated chips were almost the same as the original wood; this indicates that very little other than the water soluble material had been removed.

At 145°C and 170°C and with increasing retention time, the amount of material removed increased. It was decided that for further pulping trials prehydrolysis conditions should be 1 hour to reach temperature of 170°C and ½ hour at this temperature. The conditions were chosen because 16% of the original material had been removed but this loss was almost entirely of water solubles and hemicelluloses; the loss of alpha-cellulose being only 1.2%. Longer retention at 170°C increased the amount of material removed but the loss of alpha-cellulose became more appreciable.

Kraft digestion and bleaching of prehydrolysed chips

Details of the conditions used for pulping the prehydrolysed chips are given in Table 4.

After prehydrolysis milder digestion conditions could be used than were required for the original wood, but the mildness lay more in shorter digestion times than in lower chemical charge. This indicated that the prehydrolysed chips were more easily penetrated by the cooking liquor, but that because prehydrolysis had only a small effect on the lignin content, the total alkali required could not be much reduced. The yield was predictably low at 34 to 35% on original wood, but the alpha-cellulose contents of the unbleached pulps were about 5% higher than those of ordinary kraft pulps. The viscosities of the unbleached pulps from prehydrolysed chips were about 5 to 10 cp lower than those of ordinary kraft pulps. Further study of conditions of prehydrolysis was desirable, but this was not possible in the time available.

In bleaching the pulps from prehydrolysed chips it was decided to use a CEDED sequence, because, although both CEDED and CEHEH sequences had caused appreciable degradation as indicated by reduced viscosity, the effect of CEDED

Table 3

***Pinus caribaea* from Sabah, 9 year old sample**

Prehydrolysis conditions and analyses of prehydrolysed chips

Cook Number	Max temp, °C	Time at max temp, hours	pH of liquor at end of hydrolysis	Yield* per cent OD wood	Holocellulose		Alpha-Cellulose		Lignin	
					on OD chips* %	on OD original wood %	on OD chips* %	on OD original wood %	on OD chips* %	on OD original wood %
Original wood						61.7		40.9		30.2
BPH 1	120	0.5	3.8	97.8	62.7	61.3	43.3	42.3	30.5	29.8
BPH 2	120	1.0	3.8	97.0	66.2	64.2	44.9	43.5	30.3	29.4
BPH 3	120	1.5	3.6	96.6	64.3	62.1	43.8	42.3	30.5	29.5
BPH 4	145	0.5	3.6	94.6	62.5	59.1	44.5	42.1	31.5	29.8
BPH 5	145	1.0	3.4	92.4	56.2	51.9	41.0	37.9	34.3	31.7
BPH 6	145	1.5	3.3	88.6	57.3	50.8	43.1	38.2	34.3	30.4
BPH 7	170	0.5	3.4	84.0	58.8	49.4	47.2	39.7	35.9	30.2
BPH 8	170	1.0	3.3	79.8	60.2	48.0	48.4	38.6	36.6	29.2
BPH 9	170	1.5	3.2	76.6	59.8	45.8	48.7	37.3	37.5	28.7

Note: 1. Time to maximum temperature was one hour and water to wood ratio was 6:1

2. Water without added chemicals was used for all prehydrolyses

3. All percentages on oven-dry basis

* After prehydrolysis

Table 4

***Pinus caribaea* from Sabah, 9 year old sample**

Prehydrolysis, kraft pulping, bleaching, pulp analysis

Cook Number	BK74	BK75	BK76
Prehydrolysis (water)			
Maximum Temperature, °C	170	170	170
Time to Max Temperature, hours	1	1	1
Time at Max Temperature, hours	0.5	0.5	0.5
Kraft digestion			
Active Alkali as Na_2O% on oven dry original wood	17.5	20.0	22.5
Sulphidity %	25	25	25
Ratio of liquor to oven dry wood, litre/kg	6:1	6:1	6:1
Maximum Temperature, °C	170	170	170
Time to Max Temperature, hours	1	1	1
Time at Max Temperature, hours	3	3	2
Yield			
Yield of oven dry pulp % oven dry original wood	34.6	34.7	34.5
Screenings, on 0.15 mm slits, % oven dry pulp	0.1	0.3	less than 0.1
Yield of oven dry screened pulp % oven dry wood	34.6	34.6	34.5
Analysis of screened, unbleached pulp			
Kappa Number	30.4	22.2	23.0
Holocellulose, % oven dry pulp	96.3	97.2	97.6
Alpha-cellulose, % oven dry pulp	85.0	85.1	84.3
Cuprammonium Viscosity, cp	19.0	13.0	14.4
Bleaching			
1. Chlorination (2% pulp consistency, 20°C)			
Chlorine applied as Cl_2% on oven dry unbleached pulp	7.0	5.5	5.5
2. Alkali Extraction (6% pulp consistency, 1 hour at 60°C)			
NaOH% oven dry unbleached pulp	3.0	3.0	3.0
pH	12.5	12.6	12.6
3. Chlorine Dioxide (6% pulp consistency, 2 hours at 70°C)			
Available Chlorine applied as Cl_2% oven dry unbleached pulp	2.6	2.6	2.6
pH	2.4	2.4	2.4
4. Alkali Extraction (as Stage 2)			
NaOH% oven dry unbleached pulp	1.0	1.0	1.0
pH	12.0	12.1	12.1
5. Chlorine Dioxide (as Stage 3)			
Available Chlorine applied as Cl_2% oven dry unbleached pulp	1.3	1.3	1.3
pH	3.4	3.6	3.6
Summary			
Total Available Chlorine applied as Cl_2% oven dry unbleached pulp	10.9	9.4	9.4
Yield of oven dry bleached pulp % oven dry original wood	32.7	32.7	32.9
Analysis of Bleached Pulp			
Alpha-cellulose % oven dry bleached pulp	96.3	96.2	96.0
Cuprammonium viscosity, cp	12.4	10.1	11.6
Brightness, Elrepho 457 nm filter	83.9	82.6	84.5

was less severe. It was also decided to use a higher dose of chlorine than in earlier experiments in which the brightness of the pulp was poor and almost all the chlorine added had been used.

The results of the bleaching trials are given in Table 4. The three pulps were bleached adding varying total amounts of chlorine according to their Kappa numbers. The yield in each case was approximately 33%, brightness varied from 82.6 to 84.5, alpha-cellulose from 96.0 to 96.3% and viscosity from 10.1 to 12.4 cp. Although the value for alpha-cellulose was satisfactory, those for brightness and viscosity were low. For the most lightly cooked pulp, BK74, the fall in viscosity on bleaching was nearly 7 cp (19.0 to 12.4 cp), but the fall for the other two pulps was smaller (BK75, 13.0 to 10.1 cp; BK76, 14.4 to 11.6 cp).

The fact that the unbleached pulp with the highest viscosity was the most severely affected in bleaching, indicates that the problem of low final viscosity could not be solved simply by varying the prehydrolysis-digestion to obtain an unbleached pulp with high viscosity.

COMPARISON WITH COMMERCIAL DISSOLVING PULPS

The properties of commercially available dissolving pulps are given by Rydholm as follows:

> In the production of cellophane and low-tenacity yarns and staple fiber, pulp grades of 89–91% alpha-cellulose content are usually sufficient, normally supplied at a viscosity of 20 cp TAPPI (DP about 1,000). These are mainly sulfite pulps from both softwoods and hardwoods. To produce high-tenacity yarns and wet-strength staple fiber, the alpha-cellulose content has to be higher, 93–95% for intermediate grades and 96–98% for the highest grades. The viscosity of such pulps is less standardized and frequently below 20 cp in the case of prehydrolysis-kraft pulps (from softwoods as well as hardwoods) and much higher, 50–70 cp, for the purified sulfite pulps. The pulp brightness is often below 90% GE for a cord or cellophane pulp but normally 92–95% GE in pulps for textile purposes.[5]

In Table 5 brief details are given of the three most promising pulps prepared from *Pinus caribaea* during this investigation and of a number of commercial pulps.

Table 5

Comparison of *Pinus caribaea* bleached pulps and commercial grades

		Brightness Elrepho	Alpha-cellulose %	Tappi cuprammonium viscosity cp
P. caribaea bleached prehydrolysis kraft pulps				
BK74	CEDED	83.9	96.3	12.4
BK75	CEDED	82.6	96.2	10.1
BK76	CEDED	84.5	96.0	11.6
Commercial pulps prehydrolysis kraft process		GE		
Pine-high tenacity[5]		88	96	20
Gum*-high tenacity[5]		91	98	20
Gum*-staple fibre[5]		89	94	9
Softwood[6]			94.8	26
Hardwood[6]			96	23
Hardwood for cord rayon[7]			97.4	22

*Gum—*Eucalyptus* species

CONCLUSIONS

Showing that a pulp has a satisfactory alpha-cellulose content, viscosity and brightness is only the first stage in assessing the suitability of a pulp for dissolving. Before final conclusions can be reached many further tests of a specialised nature are required. Further, the time available for this investigation was limited and therefore our conclusions are only indications of the way further work might go. The following tentative conclusions were drawn:

1. It was not possible to produce a dissolving grade pulp from this *Pinus caribaea* by a simple kraft pulping and bleaching process.
2. In bleaching, using equal quantities of total chlorine, hypochlorite gives a greater reduction in viscosity than chlorine dioxide but a higher brightness. It is tentatively concluded that a bleaching sequence using chlorine dioxide is more promising.

3. In investigating conditions for water prehydrolyses it was found that at 120° C only the material that was water soluble was removed; at higher temperatures hemi-celluloses were removed preferentially, but with prolonged times at higher temperatures appreciable quantities of alpha-cellulose were also removed.

4. Using a sequence of prehydrolysis, kraft digestion and five stage bleaching with chlorine dioxide; pulps were obtained in a yield of about 33% with alpha-cellulose contents of about 96%, brightnesses of 82 to 85 and cuprammonium viscosities of 10.1 to 12.4 cp. Compared with commercial dissolving pulps these pulps prepared from this sample of *P. caribaea* had satisfactory alpha-cellulose contents, low brightnesses and viscosities which were low, but acceptable for some purposes.

5. Further study is required of prehydrolysis, pulping and bleaching conditions in order to determine optimum conditions.

References

1 PALMER, E. R. and GIBBS, J. A. (1971) Pulping characteristics of nine year old *Pinus caribaea* from Sabah *Trop. Prod. Inst. Report* L25.

2 TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY *TAPPI Standard and suggested methods.* New York: TAPPI.

3 WISE, L. E., D'ADDIECO, A. A. and MURPHY, M. (1946) Chlorite holocellulose, its fractionation and bearing on summative wood analysis and on studies on the hemicelluloses. *Paper Trade J.,* 122 (2), 35.

4 CASEY, J. P. (1960) *Pulp and paper chemistry and chemical technology; Vol 1, Pulping and bleaching,* p 75. New York and London: Interscience Publishers.

5 RYDHOLM, S. A. (1965) *Pulping processes,* p 1177. New York and London: Interscience Publishers.

6 AVELA, E., ERVA, J., HACKMAN, B., *et al.* (1967) Sulphite pulps for HWM-fibres. *Proc. Int. Sump. on Dissolving Pulps, Finland, 1966.* London: Butterworth.

7 SINCLAIR, F. (1967) Polynosic fibres from different types of dissolving pulps. *Proc. Int. Symp. on Dissolving Pulps, Finland, 1966.* London: Butterworth.

(853) Dd817398 1,500 4/73 HP Ltd., So'ton G3313